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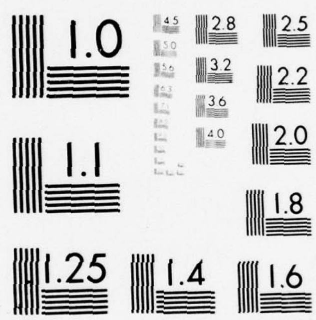

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FEASIBILITY OF TACTICAL USMC VSTOL AIRCRAFT OPERATIONS ABOARD MERCHANT SHIPS 1990-2000

by

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EXECUTIVE SUMMARY

An analysis of potential world trouble spots and consideration of the means of applying combined air and ground combat power at these locations reveal trends which will challenge the United States armed forces. First, the more independent stance of heretofore cooperative countries can predictably lead to loss of bases and overflight rights, or at best restrictions on base and airspace use. Second, reduced numbers of U.S. Navy ships will reduce the U.S. combat power, specifically tactical air power, which can be applied at a given time and place in the world. While these trends fall into areas of interest to the Navy and Marine Corps, they also affect the mission performance of the other armed services. Even with unlimited air refueling, crew fatigue places finite limits on the ferry range of tactical aircraft.

Because of its air-ground team concept and its emphasis on VSTOL aircraft, the Marine Corps can pursue a unique alternative method of reaching the objective area with its TACAIR assets: the use of selected merchant ships as platforms for VSTOL aircraft operations. Development of this capability is not dependent on dramatic technological breakthrough; the emphasis in this study is on the integration and use of hardware that is already in existence or under design.

Examination of aircraft unit requirements, including equipment and consumables, and ship characteristics resulted

in the tentative identification of three suitable ship types: Non-self-sustaining containerships, Roll On/Roll Off (RO/RO) ships, and SEABEE barge carriers, All of these ships have long ranges, speed in excess of 20 knots, relatively unobstructed topside space for aircraft operations, and sufficient capacity to accommodate an aircraft unit and still transport some other tactical cargo for the operation.

A combination of commercial freight containers and Marine Corps expeditionary shelters, designed to ISO specifications, can be embarked quickly aboard chartered or requisitioned vessels to provide facilities and storage for the embarked unit. These facilities include living, head, messing, and other hotel modules; shop space; electrical power and fresh water production; fuel and ordnance; and all other essentials so as to make the embarked unit nearly independent of the host ship. A "flight deck" for takeoffs and landings may be constructed atop the topside containers. Both the containership and RO/RO will require installation of an elevator or ramp for movement of aircraft if it is desired that they be carried on decks other than the "flight deck." The SEABEE has an integral elevator which should be adaptable to aircraft movement.

Within the scope of this study, the operation of tactical VSTOL aircraft from many properly configured merchant ships appears to be feasible, although a merchant ship will probably not be as effective as a warship designed for combat operations. The required installation can be made up

predominately from hardware which is either in existence or already under design. The most practical and economically viable employment case would probably be approximately 20 airplanes capable of limited operations (deck alert, etc.) in transit and approximately five days of operations in the amphibious objective area. Some relatively simple national defense features, such as larger ramps aboard RO/RO ships, combined with additional VSTOL design criteria, will enhance the compatibility of the ships and airplanes. While sortie rates will probably be limited by restricted movement between decks and by supplies of aviation fuel, merchant ships may represent the only available means of moving tactical aircraft to some combat areas in the numbers required.

It is intended that VSTOL aircraft aboard merchant ships will complement, rather than replace, carrier based naval aviation. Embarked VSTOL aircraft will also be dependent on other Navy ships for command and control until such facilities are established ashore. Once Marine aviation units have established operations ashore, the aircraft carriers are free to pursue other missions. This becomes particularly advantageous at higher threat levels if the enemy has the capability to reinforce and contest air and sea superiority.

Further analysis by a working group, composed of experts from technical disciplines and such fields as maritime safety and international law, is recommended. This group

should orient its efforts toward analysis of engineering soundness, effectiveness, safety, survivability, and legality of this concept. Their goals should be the establishment of an operational requirement, definition of hardware requirements, installation of a prototype kit, and flight tests at sea.

Abstract of

FEASIBILITY OF TACTICAL USMC VSTOL AIRCRAFT

OPERATIONS ABOARD MERCHANT SHIPS

1990-2000

Two trends indicate a potential problem in the movement of tactical aircraft, specifically Marine Corps tactical aircraft, to combat areas in a large portion of the world. Reduced numbers of U.S. Navy ships and constrained basing and overflight rights may limit access to those combat areas which can be reached by air-refueled ferry flights from U.S. bases. Relatively simple modifications to some newer ships in the U.S. merchant fleet will permit flight operations by present and proposed inventories of USMC vertical and short takeoff and landing (VSTOL) aircraft. Shipboard requirements are identified and potential ship installations are suggested. Emphasis is placed on integration of existing or already proposed hardware to increase the tactical air firepower which may be brought to bear in remote geographic areas of national interest.

PREFACE

This topic was suggested by staff officers at Headquarters United States Marine Corps to investigate a potential void in the employment concept for Marine tactical aviation assets. Although written references were available on many subsystems and peripheral issues used in this concept, there has been, to the best of the author's knowledge, no previous investigation of this exact subject. For this reason, a great deal of the research was in the form of ship visits and personal conversations with knowledgeable authorities in various disciplines; these contacts were invaluable. Interpretations and opinions are based on the author's experience aboard ship, in VSTOL aircraft operations, and as a participant in numerous amphibious operations.

This study does not attempt to be as detailed as will be necessary to actually undertake this project, i.e., it is not a "how to" manual. It has the more limited objective of identifying those items and areas which could support or inhibit this unique concept. Because of time limitations, the study is by no means exhaustive. A number of detailed engineering studies will be required to verify actual requirements. While use of existing or already proposed hardware has been emphasized, it is almost certain that some new items must be designed and purchased. Finally, after hardware has been purchased and installed, flight tests and operations appraisal/evaluation must be performed.

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TABLE OF CONTENTS

CHAPTER | PAGE

LIST OF TABLES

LIST OF ILLUSTRATIONS

FEASIBILITY OF TACTICAL USMC VSTOL AIRCRAFT OPERATIONS ABOARD MERCHANT SHIPS 1990-2000

CHAPTER I

INTRODUCTION

The Requirement

The mission of the United States Navy, as stated in Title 10, U.S. Code is to be prepared for "...prompt and sustained combat incident to operations at sea." To fulfill this mission, the Navy has two basic functions--sea control and power projection.

The mission of the United States Marine Corps, also set forth in Title 10, U.S. Code, includes the following specific functions:

> To provide Fleet Marine Forces of combined arms, together with supporting air components, for service with the fleet in the seizure or defense of advance naval bases and for the conduct of such land operations as may be essential to the prosecution of a naval campaign.
>
> To develop, in coordination with the other Services, the doctrines, tactics, techniques, and equipment employed by landing forces in amphibious operations.

The naval campaign alluded to above could be in connection with either of the Navy's principal functions--sea control or power projection.

An amphibious operation, by its very nature, calls for a rapid buildup of combat power ashore, starting at zero and moving afloat assets across the beach as quickly as they can be employed. The continuous, uninterrupted transition of supporting arms from sea-based to shore-based employment is particularly vital. Sea-based tactical aviation and naval gunfire are relieved by shore-based aviation and artillery as soon as adequate locations ashore are available. As the threat environment becomes more intense, rapid phasing ashore is particularly important so that precious shipping can depart the amphibious objective area (AOA). Also, if one assumes a 12 carrier fleet (six on each coast, typically four operational) the Navy may be hard pressed to devote two CVs for an extended time period in order to provide round-the-clock support to the landing force.

Marine tactical aviation units have the training and equipment to operate from ships and from austere bases ashore. They are often described as the "swing force" that can be employed wherever and whenever they can most effectively accomplish the fleet commander's mission. In spite of this capability to phase ashore, Marine TACAIR units have rarely been permitted to execute this evolution in the classic manner. With the present and projected shortage of carriers the Navy cannot afford to devote carrier decks for exclusive use by Marine aviation units. Marine squadrons assigned to carrier air wings (CVWs) may indeed be

involved in amphibious operations aboard ships of the Support Carrier Group, but when an aircraft carrier leaves the AOA, the Marine squadrons embarked thereon remain with the CVW rather than phasing ashore. At no time in this typical scenario do these CV-based Marine aviation assets come under the command of the Landing Force Commander. Landing force tactical aviation assets are typically not available until airfields ashore are captured or built and the airplanes and equipment ferried into the AOA. An obvious exception is the case in which bases are available in friendly territory close enough to support the amphibious operation. Under many typical scenarios, however, the firepower of Marine tactical aviation is not available to the CLF or CATF until well after D-day.

With the introduction of VSTOL aircraft into the inventory, Marine tactical aviation units have the capability to operate from forward sites ashore at an earlier time than heretofore has been possible. In addition, the ability to operate from a variety of ships without catapults or arresting gear tremendously expands the numbers of sea-based platforms available. VSTOL airplanes have been successfully operated from amphibious ships down to LPD-size and have made extended cruises aboard LPH ships. They have been integrated into the operations of helicopters and have proven that they can support the amphibious assault without interfering with the transport helicopters.

Unfortunately, the embarkation of tactical VSTOL airplanes aboard amphibious ships, while successful, displaces rotary wing assets which are vital to the ship-to-shore movement. Ordnance for VSTOL airplanes displaces valuable landing force munitions (LFORM) in the ship's magazines. The projected fleet of five LHA and seven LPH will provide approximately 400 CH-46 equivalent deck spots, all of which can be filled with Marine Corps helicopters, if one assumes that time is available to assemble helicopters from all three Marine aircraft wings located on each coast of CONUS and in WESTPAC. In addition to the helicopters required by the landing force, it is almost certain that some deck spaces aboard amphibious ships will be required for such ancillary missions as airborne mine countermeasures (AMCM).

Combat flights and ferry flights into the AOA will be drastically curtailed in the event of continued erosion of basing rights and overflight rights. Recent experience demonstrates that the use of a nominal ally's soil or airspace for our unilateral purposes is totally dependent on the political climate in the host country. Almost every major overseas base is subject to periodic renegotiation; notable examples of strategically important foreign bases are those in Iceland, Spain, the Azores, Italy, the Philippines, and Japan.

Flights through international airspace are accepted under international law. However, overflight of a foreign

country, or through airspace over a country's territorial waters, is totally at the pleasure of the host country. Airspace transit rights do not automatically follow rights of free transit or innocent passage of surface ships through a strait. Although the current draft of the Law of the Sea Treaty (15 July 1977) provides equivalent rights for ships and aircraft, it may be possible, in future years, to have free transit of surface ships through a strait (such as Gibraltar or Malacca) over which aircraft flight would be curtailed by the adjacent countries, unless an international agreement is in effect.[1]

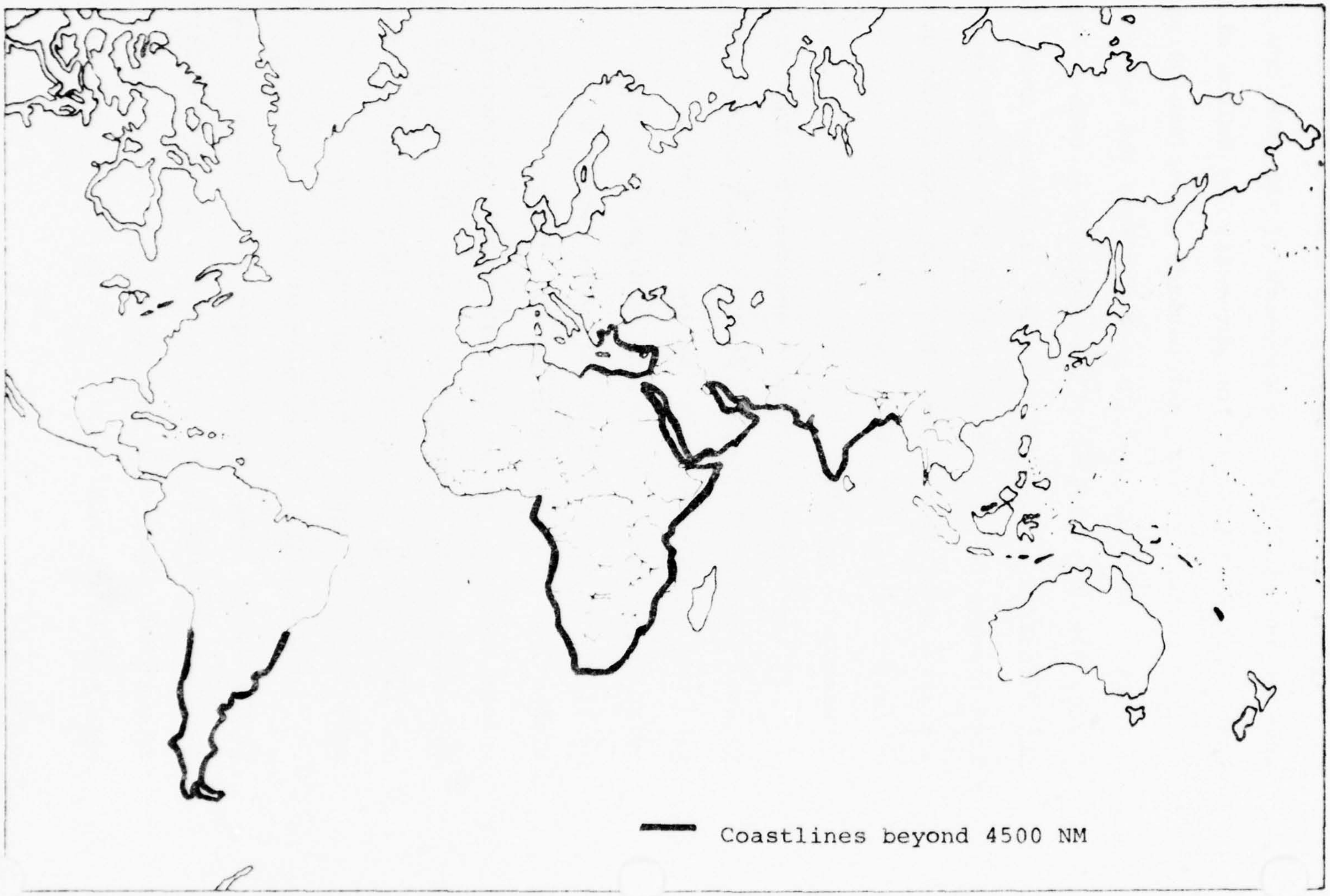
If one accepts current transoceanic flight doctrine (which requires sufficient fuel to reach either the destination or the starting point in the event of a missed aerial refueling point), a practical maximum ferry range for Marine tactical airplanes (circa 1990-2000) would be approximately 4500 miles. Using this criterion, Figure 1 depicts those coastal areas of the world that cannot be reached by a 4500 mile flight from bases on U.S. soil (including Guam and Puerto Rico) assuming free flight through straits, but avoiding overflight of foreign territory.

Incidentally, the problem of moving tactical aircraft to the combat area is not unique to the Marine Corps. If the base and overflight situation dictates long ferry flights from CONUS, there is a practical limit to the ferry range of single-piloted tactical aircraft due to aircrew fatigue

FIGURE 1

COASTLINES BEYOND 4500NM FERRY RANGE

(FLIGHT IN INTERNATIONAL AIRSPACE OR THROUGH STRAITS)



considerations. Even though a high capacity escort tanker is available, there is a finite, though poorly defined, flight time limit beyond which a flight becomes unsafe and eventually unbearable. At 450 knots, a 10 hour, 4500 mile flight probably approaches that limit.

Therefore, with the current and projected shortage of deck space aboard Navy ships, and the potential impossibility or impracticality of ferry flights to the AOA, it is vital that alternative methods of movement be investigated. This study will examine one of those alternatives: the operation of Marine tactical VSTOL aircraft aboard selected merchant ships.

Assumptions

In order to define the scope of this study, the following assumptions have been made:

a. That an ability to project power ashore in support of national policy will remain a valid military requirement.

b. That the missions and organizational structure of the Navy and Marine Corps will remain essentially unchanged.

c. That VSTOL technology continues to develop at a reasonable rate; i.e., that a significant portion of Marine TACAIR will be composed of VSTOL aircraft.[2]

d. That sufficient numbers of U.S. Flag merchant ships can be made available on a suitable time schedule to be configured and used for an amphibious operation.[3]

CHAPTER II

EMPLOYMENT CONCEPTS

Three modes of employment merit examination:

(1) Use of merchant shipping for aircraft transportion only, including lift on/off and fly on/off options,

(2) Limited operations enroute and less than five days operation in the AOA, and

(3) Full scale operations enroute and in the AOA.

Transportation Only

With only minimal preparation time, many ships can be configured for vertical takeoffs and landings by VSTOL aircraft. In most instances, this will be the safest and most efficient method of loading and offloading. By providing a vertical takeoff and landing (VTOL) surface, airplanes can be recovered aboard ship for transit and launched to shore bases upon reaching the AOA. If the ship's configuration permits, aircraft can be cleaned and turnedup periodically in order to minimize preservation requirements. In order to preserve unit integrity, it is desirable that all personnel and equipment be embarked even though flight operations will not be conducted until flyoff; however, this requirement could limit the number of ships found to be suitable for this option.

The principal factors that could militate against the fly on/off option are:

a. Inability to move aircraft from VTOL area to storage area, i.e., lower decks.

b. Extensive preservation/depreservation which could not be performed aboard ship.

c. Obstructions preventing safe flight operations.

If these or other factors prevent fly on/off, then aircraft must be lifted or rolled on and off from lighters or at pierside. This method would not take advantage of VSTOL capability (unless, of course, the airplanes were recovered and launched from the pier or lighter) and the problems attendant to this mode of transportation should be identical to the same evolution with conventional airplanes. The only real requirements would be physical security (tiedowns, etc.) and protection from the wind and sea. Tactical airplanes have, on occasion, been transported by civilian shipping, although rarely in recent years. Typically, however, they were in a state of maximum preservation, defueled, and often had the engines removed and shipped separately.[1] The lift on/off option is not a valid concept for supporting combat operations in the AOA, and will not be addressed further in this study.

<u>Limited Operations</u>

Limited Operations, for the purpose of this study, are defined as (1) enroute deck alert (for air or surface threat) and (2) five days of operations in the AOA prior to movement ashore. The enroute deck alert would normally be in support

of a larger aviation force (CV task group) or in a relatively low intensity threat. This deck alert could add to the defensive posture of a convoy without excessive requirements upon the ship or embarked aviation unit. Ideally, control of aircraft for both AAW and ASUW operations enroute would be performed by combatant ships in company. Once in the AOA, the Tactical Air Command Center (TACC), initially afloat, would assume control of the embarked aircraft until control is passed ashore.

The limited operations option would still require all the shipboard facilities and personnel of the full scale operations option. The only tangible saving would be aircraft consumablessuch as fuel, liquid oxygen, and ordnance. As discussed later, aviation fuel may be the most precious commodity aboard ship. For computation purposes, during the "limited" option, no consumable items are programmed for operations enroute to the AOA. Those items used enroute must be replenished or AOA operations reduced by an appropriate amount.

Full Scale Operations

This employment mode may be thought of as being essentially identical to CV-type operations. Airborne CAP and surface search missions would be conducted enroute, and preplanned and on call missions would be flown upon arrival in the AOA. Sustained flight operations would be possible for approximately 12 hours per day, or some reduced level of

operations could be sustained on a round-the-clock basis. Although there will be few additional requirements for facilities (over limited operations employment, above), there is clearly a difference in the total amount of consumables required. If, however, one assumes an operational routine of resupply every five days (typically the case, even with deployed aircraft carriers), then the full scale alternative would not require additional storage space for embarked materiel over the limited operations alternative.

Number of Airplanes

Three sizes of embarked units will be addressed in order to obtain a range of alternatives. For convenience, the sizes chosen include a six plane detachment, a 20 plane squadron, and two 20 plane squadrons, the latter with a skeleton Marine aircraft group headquarters. All units include an intermediate maintenance activity (IMA), although the IMA need not necessarily be operational enroute for study purposes.

Employment cases have been summarized in Table I and will be addressed by number throughout the text.

TABLE I

EMPLOYMENT CASES

	Detachment (6 A/C)	Squadron (20 A/C)	Two Squadrons (40 A/C0
Transportation Only	1	2	3
Limited Operations	4	5	6
Full Scale Operations	7	8	9

CHAPTER III

AIRPLANE CHARACTERISTICS

Characteristics such as size and weight of embarked airplanes will determine or at least influence the facilities required to accommodate the aircraft aboard ship, and may determine whether or not a particular ship can be used at all. Indirectly, capabilities of the aircraft to perform specific missions will influence utilization and employment (both in transit and in the AOA) which will, in turn, dictate requirements for such consumables as fuel, ordnance, and oxygen, as well as the physical installations to support the missions assigned. This discussion of airplane characteristics will occasionally refer to models or generic classes of aircraft as examples. However, no attempt will be made to specify a ship installation or even a concept of employment based on a specific type aircraft. These examples are used only as likely possibilities of a tactical VSTOL aircraft for the 1990-2000 period.

Three general categories of design have been pursued for high performance VSTOL airplanes. These are (1) vectored thrust (2) lift plus lift-cruise and (3) thrust augmented wing. Each of these designs has unique characteristics, advantages, and disadvantages which merit brief discussion.

Vectored Thrust

The vectored thrust design is best typified by the AV-8 series airplane (Figure 2). The exhaust gases are discharged through nozzles which rotate to deflect the thrust either aft or down, with the same engine used for powered lift and conventional flight. In the case of the AV-8 series, four nozzles are used. Fan air (from the forward portion of the compressor) is discharged through two nozzles--one on each side of the fuselage--while turbine discharge air flows out two corresponding aft nozzles. The four nozzles, driven by an air motor servo, move simultaneously in response to a cockpit control. A reaction control system (RCS) is provided for attitude control at low speeds where aerodynamic control is ineffective. The RCS uses hot gases from the engine combustion section, exhausted at the nose, tail, and wingtips in response to the pilot's control movements, to control the attitude of the airplane.

The vectored thrust design has the advantages of relative simplicity, moderate footprint (temperature and velocity of exhaust gases on the vertical takeoff (VTO) and vertical landing (VL) surface) and, perhaps most important, the ability to reorient the engine thrust vector throughout a large portion of the aircraft flight envelope. The last characteristic can dramatically increase the effectiveness of an airplane during air combat maneuvering (ACM). While the AV-8 series is essentially subsonic, a vectored

FIGURE 2

AV-8A "HARRIER"

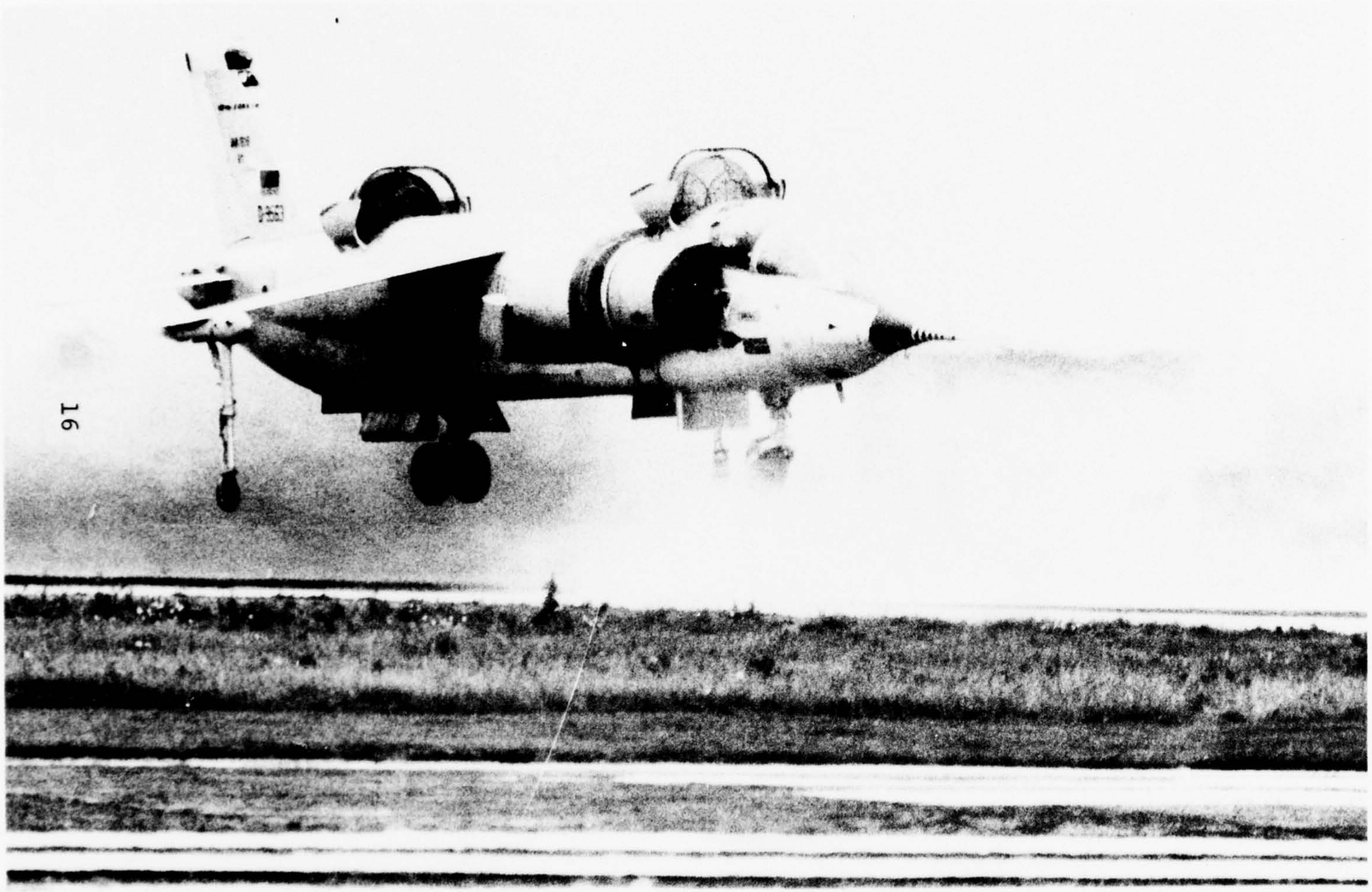
thrust airplane could be designed to achieve up to approximately 1.5 mach number if afterburning and/or plenum chamber burning were employed.

Lift Plus Lift-Cruise

The lift plus lift-cruise (L+LC) design, as used, for example, in the German VAK-191 (Figure 3) and the Soviet YAK-36 "Forger," embodies one main (lift-cruise) engine with a swiveling tailpipe--to direct jet exhaust either aft or down--and one or more lift engines mounted vertically. For low speed attitude control, the L+LC design uses variations of RPM or exhaust geometry on the engines, and may incorporate an RCS. The L+LC concept can provide very good vertical takeoff (VTO) performance as a result of the increased vertical thrust of the pure lift engines. (A small contemporary jet engine can produce thrust equal to five or more times its installed weight.) An L+LC airplane can be designed with aerodynamic characteristics and a tailpipe configuration suitable for supersonic level flight performance equal to that of a conventional takeoff and landing (CTOL) airplane. The disadvantages of a L+LC design are numerous. The footprint during a VTO shows the highest temperature and velocity of any of the three designs; therefore, erosion of the takeoff and landing surface must be considered. The VAK-191 even causes high surface temperatures during starting of the lift engines, although this is reported by flight test engineers to be a result of improper fuel control

FIGURE 3

VAK-191B[1]



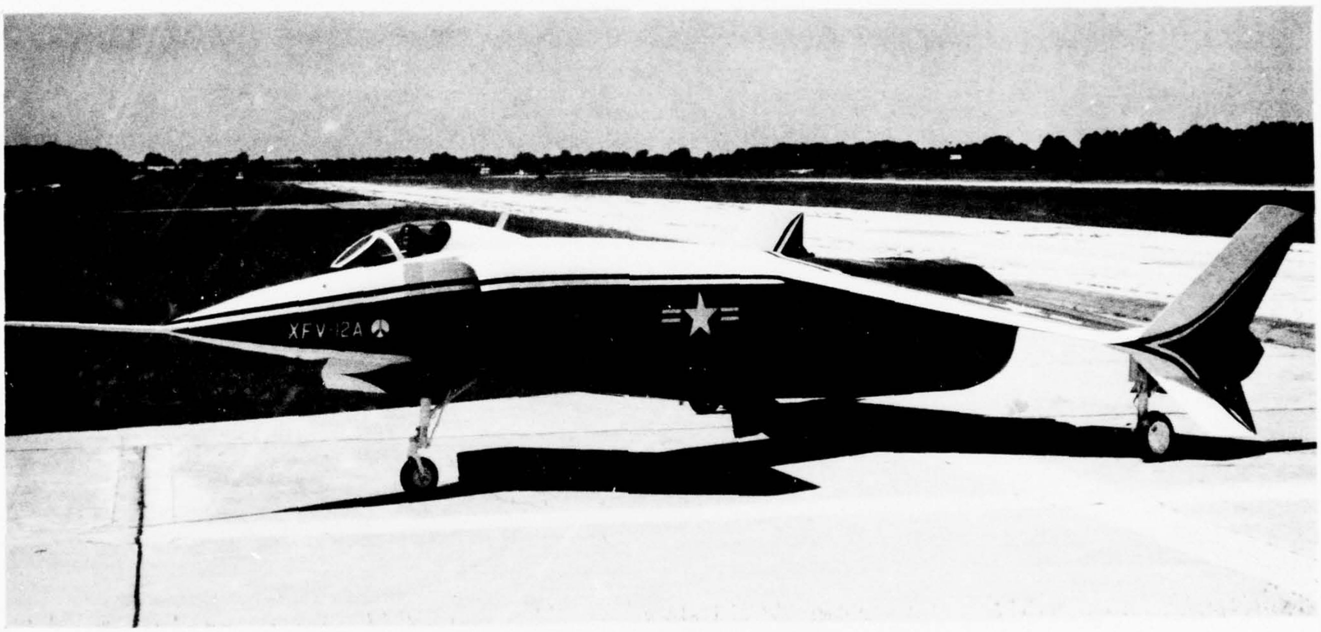
scheduling. Use of the lift engines for thrust vectoring in forward flight (VIFF) during ACM, is impractical, since they normally require several seconds for startup. Additional installed engines normally increase complexity, maintenance, and logistic requirements. The short takeoff (STO), wherein some takeoff roll is used to increase payload and reduce surface damage is a very complicated, high workload maneuver in an L+LC airplane. This is due to the difficulty in controlling the moments created by two or three engines so that they are precisely balanced at the instant of liftoff. By contrast, a STO in a vectored thrust airplane is a relatively easy, simple maneuver.

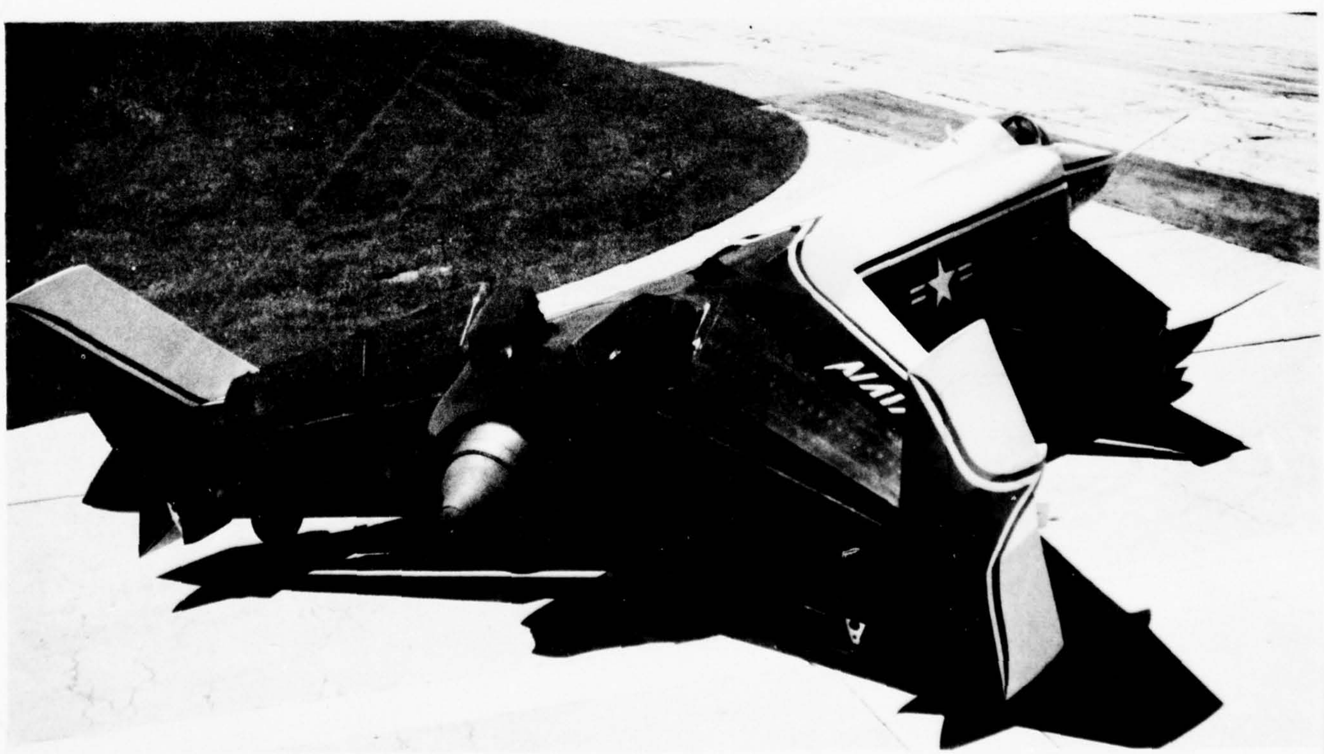
Thrust Augmented Wing

The thrust augmented wing (TAW) design as embodied in the XFV-12A (Figure 4) has been demonstrated in wind tunnel tests but has not been actually flown. In a TAW design, powered lift flight is achieved by diverting jet engine exhaust into ducts running the length of the wings and horizontal stabilizer or canard. The hot gases are discharged downward through nozzles and draw air (from the top of the wing surface) through a louver arrangement, the air-hot gas mixture being then discharged out the bottom of the wing through a similar louver or "augmenter" arrangement. The magnitude and direction of the thrust vector is determined by the position of the two augmenters on the lower surface of the wing. The vertical thrust created by this augmentation

FIGURE 4

XFV-12A





scheme is greater than that of the basic jet engine providing the hot gases, principally as a result of increased mass flow. Augmentation can theoretically double the vertical thrust available, although this augmentation ratio of 2.0 has never been demonstrated in wind tunnel tests. Up to 1.5-1.6 is believed to be practicable in a production aircraft. Attitude and altitude control in a TAW airplane is provided by a mixer box which takes altitude and attitude control inputs and commands a unique position for each wing and empennage or canard augmenter.

With the augmenter doors closed and the diverter positioned to discharge engine exhaust out the tailpipe, the TAW airplane is capable of conventional wingborne flight. This design lends itself quite well to installation of an afterburner and should have supersonic capability equivalent to that of a CTOL airplane. The footprint under the TAW airplane is the least harsh of any of the designs under consideration. The TAW design has a number of disadvantages: it is the most complex of the designs and is based on unproven technology. Stores carriage is restricted to near-centerline or wingtip stations. Short takeoffs would probably be a complex, high workload maneuver. Folding wings might not be practicable.

Footprint

Table II depicts typical footprint characteristics of operational or developmental airplanes from the three design

TABLE II

TYPICAL FOOTPRINT CHARACTERISTICS

AT SURFACE DURING VTO

	Max Temperature °F	Max Pressure lb/sq ft	Max Velocity ft/sec
AV-8A	1000	2600	400
VAK-191B	1200+	1400+	1000+
XFV-12A	240-300	300-325	100+

categories discussed. Because of differences in instrumentation and test techniques, the figures shown should be considered as approximate only, but they do serve to illustrate the vast variation in effects on the takeoff and landing surface.

Design Comparisons

Table III summarizes the relative rankings of the three designs. These ratings are qualitative, and are intended only to show relative utility or desirability in each area of interest. Number "1" indicates most desirable or most effective; number "3" the least desirable or effective. The same number assigned to two designs indicates essential equality.

Airplane Size

The size of an embarked airplane will obviously have a great impact on suitability of a candidate ship, number

TABLE III

VSTOL DESIGN RANKING

CHARACTERISTIC	Vectored Thrust	L+LC	TAW
VTO Performance	2	1	3
Supersonic Potential	2	1	1
Simplicity	1	2	3
Demonstrated Operational Capability	1	2	3
VIFF Capability*	1	2	2
Stores Carriage Flexibility	1	1	2
Moderate Footprint	2	3	1

* Thrust vectoring in forward flight

of airplanes to be embarked, operational procedures, and numerous other areas of interest. While it is impossible to forecast the size of a future aircraft with certainty, it is possible to observe the range of sizes of present aircraft and perform some extrapolation. In general, the capabilities with which an airplane is to be designed (range, speed, payload, weapon system, etc.) will determine airplane size and weight within fairly narrow tolerances. For example, if an airplane is to have the capability of an F-18, it will probably be close to the size and weight of an F-18. This method of forecasting size is quite subjective, but

will generally err on the conservative side; i.e., new technology usually results in modest reduction of avionics, structural and machinery size and weight, but not the degree initially expected by optimistic designers. For these reasons, in the selection of candidate ships for future aircraft the size of existing aircraft can be a very useful guideline.[2] Table IV contains dimensions of several contemporary and proposed aircraft types, including some purely experimental VSTOL models.

TABLE IV

AIRPLANE DIMENSIONS (FT-IN)[3]

	LENGTH	WING SPAN SPREAD/FOLDED	HEIGHT	A-7 SPOTTING FACTOR[4]
A-4M	40-3*	27-6/-	15-0	0.82
A-6E	54-7	53-0/25-4	16-3	1.40
AV-8A	45-6	25-3/-	11-3	0.80
AV-8B	42-10	30-4/-	11-3	0.86
F-4J	58-3	38-5/27-6	16-3	1.44
F-14A	62-0	64-2/33-0**	16-0	1.54
F-18A	56-0	40-8/25-0	15-4	1.18
XFV-12A	44-0	25-0/-	15-0	UNK
VAK-191B	48-4	20-2/-	14-1	UNK
YAK-36	57-6	27-0/UNK	14-9	UNK
USN VSTOL "A"***	51-6	53-6/29-8	19-0	1.32
USN VSTOL "B"***	57-0 to 61-0	34-0 to 40-0/21-0	16-6	1.29

* Excluding refueling probe
** Oversweep position for carrier stowage
*** Approximate dimensions for notional subsonic and supersonic VSTOL designs.

CHAPTER IV

SHIPBOARD REQUIREMENTS

Embarkation requirements for a unit flying yet-to-be-defined airplanes is, at best, a precarious undertaking. Therefore, the numerical values used herein represent the best estimates of the author, based on research of available data and interviews with knowledgeable individuals. While these numbers will, of course, require refinement as better information becomes available, such refinement should not drastically alter the viability of the concept under study.

Previous Studies

One of the more comprehensive studies of aircraft employment aboard merchant ships is the Reserve Merchant Ship Defense System (RMSDS), commonly called the Arapaho program. Arapaho envisions deployments of antisubmarine (ASW) helicopters aboard selected merchant ships for convoy protection. Before the program was suspended due to shortage of funds, a number of shipboard modules were designed as living and working spaces housed in freight container-like shells. Although no deployments or operations were performed, a number of these modules were actually constructed and are now located at the old Naval Air Station in New York awaiting completion.[1-7]

In addition, the Marine Corps Expeditionary Shelter System (MCESS) study has identified a family of container-compatible shelters (shown in Figure 5) for facilities which can be used aboard ship, then lifted ashore for the landing force. The family of "small" shelters (8'x8'x20') meet International Organization for Standardization (ISO) requirements for use aboard container ships. They can be configured for a variety of uses, such as berthing, heads, mess, laundry, sickbay, etc., and were designed with uses such as Arapaho in mind. Table V shows typical shelter requirements for various numbers of embarked troops. It should be noted that Table V does not include aircraft shop or working space requirements.

Regardless of the employment mode (Table I), two shipboard facilities will be required: a takeoff and landing area and crash/rescue assets. These will be discussed in order.

Takeoff and Landing Area

All the candidate ships will require the installation of a surface for takeoffs and landings. This surface should be flat, clear of obstructions, have good traction, and, of course, be capable of supporting the weight of embarked aircraft. AM-2 matting is an ideal surface, although other similar materials could be suitable. If the surface is elevated a few feet above the deck, for example above hatch

FIGURE 5

ARTIST CONCEPT OF USMC STANDARD FAMILY OF SHELTERS

covers, a grille or grid-type surface may be desirable. Such a surface may be lighter and easier to install. In addition, use of a grille-type surface will prevent re-ingestion of exhaust gases and ground effect, possibly resulting in an actual VTO performance improvement in some VSTOL aircraft. However, influence of ground effect on VTO performance is totally dependent on aircraft design features. For example, recent installation of lift improvement devices improves AV-8 vertical performance from a solid surface. Due to its availability, AM-2 matting, properly anchored to the deck or to the top if a layer of containers, is probably the most desirable surface material. In order to properly distribute the load on top of containers, some type of beam structure will probably be required.[8]

For the AV-8 series aircraft or smaller, a vertical landing (VL) area of about 72 by 72 feet may be acceptable. For larger aircraft, aircraft without good control response in ground effect, or for operations during large deck motion excursions, a larger surface will be required. In this writer's opinion, planners should strive for a landing area 100 by 100 feet to accomodate future VSTOL airplanes, although actual requirements must be verified by flight tests.

The takeoff area, which will probably be an extension of the landing area, or, perhaps, even the same area, can probably be constructed of the same material. If pure VTOs are envisioned, the same size requirements exist. However,

if, as is likely to be the case, a significantly larger payload can be carried via a short takeoff (STO), then a surface to accomodate the STO should be provided. This STO area should be from 300-600 feet in length, minimum 50 feet in width, and free of obstructions. Ongoing flight tests of AV-8A launches using a "ski-jump" ramp have demonstrated typical STO length reductions of 50%.[10,11] It may be necessary, on some ships, to remove the forward mast or angle the takeoff area a few degrees off the fore and aft axis of the ship in order to provide obstruction clearance.

Crash/Rescue Equipment

Portable crash/rescue equipment and personnel should be embarked. The amount and type of such equipment will be tailored for a particular operation. On larger ships, with several aircraft embarked, the standard Marine Corps expeditionary crash truck (MB-5, MB-1, P4A, or follow-on) could be used, then moved ashore with the landing force. The Arapaho hangar modules also contain a sprinkler system. All contemporary merchant ships have CO_2 systems installed in holds and fire mains throughout. Many have installed foam systems.

Landing Aids

Visual landing aids (VLA) and electronic landing aids (ELA) may be required for shipboard flight operations.

Since these items are a scientific discipline in themselves, this discussion will be intentionally cursory and succinct. The size and complexity of the shipboard installation will be dependent upon a number of factors, including:

a. The requirement for night or all-weather flight operations.

b. Ship's deck motion during flight operations.

c. Airplane flying qualities and sufficiency of self-contained landing aids.

The requirement for a night and all-weather launch and recovery capability may increase the cost, complexity, and outfitting time of the VLA/ELA installation. If large excursions of ship motion are anticipated, the landing aid system will probably require some degree of gyro stabilization. Under most conditions, assuming moderate deck motion and good airplane flying qualities, an unstabilized Fresnel-type lens with a Manual Optical Visual Landing Aid System (MOVLAS) option and lights to outline and illuminate the landing area may be sufficient VLA.

The Navy Vertical Takeoff and Landing (NAVTOLAND) project is an attempt to improve the approach, hover, and landing capabilities of Navy and Marine VSTOL aircraft.[12,13] Conference with the cognizant Naval Air Systems Command engineer revealed that the shipboard NAVTOLAND hardware could easily be made suitable for installation aboard a merchant ship, if such requirements were stated early in program definition.[14]

It is desirable that the ship be able to remain electronically passive during flight operations, or that low probability of intercept (LPI) emissions be used. If aircraft sensors and onboard computer capabilities permit, it may be possible to incorporate a system which will provide approach and landing information to the pilot for a self-contained approach until he is close enough to perceive visual cues from the deck lighting alone. A rudimentary system with such a capability currently exists in the A-6 airplane. In the absence of TACAN or other emitting navigational aid, some type of low power transponder or other device must be provided for positive ship identification during a self-contained approach.

Personnel

A 20-plane Marine AV-8A squadron is organized and equipped to deploy as a squadron or up to two simultaneous six-plane detachments. This structure provides a great deal of flexibility without undue expense. One of the detachments (designated Det "A") has only an organizational maintenance capability (OMA). This "dependent unit detached" (DUD) is conceptually capable of a 30 day deployment away from the parent squadron with a daily logistic run to an appropriate intermediate level maintenance activity (IMA) for delivery and return of repairable components. The other detachment (Det "B") has its own IMA assets and is capable

of deployments of up to six months duration away from the parent squadron. Current plans do not envision a Det "A" for AV-8B squadrons, however a Det "B" could be deployed as a DUD by simply leaving IMA assets behind.

In addition to squadron and IMA personnel, base support personnel from other units, principally the Marine Air Base Squadron (MABS) and Marine Wing Support Group (MWSG) must be embarked if the aviation unit is to be independent of the host ship. MABS and MWSG personnel provide such services as messing, crash/rescue, bulk fuel, aerology, communications, medical and utilities. MABS and MWSG are not organized, nor are their numbers sufficient, to support all tactical units of a Marine aircraft wing in six-plane detachments. It is quite likely that they could not support even squadron-sized detachments if the entire wing were to be deployed, since base support in the expeditionary environment has historically been structured for airfields hosting one or more Marine aircraft groups.

Table VI depicts a proposed list of personnel for each employment mode. This list will require refinement as the aircraft and concept are better defined, but the numbers shown should be sufficiently accurate for initial planning.

Aircraft Maintenance and Supply Assets

Any discussion of shipboard aircraft maintenance requirements will, of necessity, be very general, pending definition

TABLE V - HOTEL FACILITY CONTAINER REQUIREMENTS [9]

NO. OF TROOPS	BERTHING UNIT 160 Sq Ft/U 10 Men/U	HEAD UNIT 160 Sq Ft/U 80 Men/U	SHOWER & LAVATORY UNIT 160 Sq Ft/U 160 Men/U	FEEDING SYSTEM UNIT 860 Sq Ft/U 1200 Men/U	MESS AREA 2000 Sq Ft/U 1200 Men/U	LAUNDRY UNIT 160 Sq Ft/U 378 Men/U	SICK BAY UNIT 640 Sq Ft/U 2100 Men/U	REFRIGERATION STORAGE UNIT 320 Sq Ft/U 444 Men/U	DRY STORAGE UNIT 160 Sq Ft/U-20' 320 Sq Ft/U-40' 500 Men/U-20' 1008 Men/U-40'	WATER PURIFICATION UNIT 480 Sq Ft/U 360 Men/U	PUMP MODULE 54 Sq Ft/U Serves 6 Units
600	60 Units 9,600 Sq Ft	8 Units 1,280 Sq Ft	4 Units 640 Sq Ft	1 Unit 960 Sq Ft	1,000 Sq Ft	2 Units 320 Sq Ft	1 Unit 640 Sq Ft	2 Units 640 Sq Ft	1 Unit 40' 320 Sq Ft	2 Units 960 Sq Ft	4 Modules 216 Sq Ft
900	90 Units 14,400 Sq Ft	11 Units 1,760 Sq Ft	6 Units 960 Sq Ft	1 Unit 960 Sq Ft	1,500 Sq Ft	3 Units 480 Sq Ft	1 Unit 640 Sq Ft	2 Units 640 Sq Ft	1 Unit 40' 320 Sq Ft	3 Units 1,440 Sq Ft	6 Modules 324 Sq Ft
1200	120 Units 19,200 Sq Ft	15 Units 2,400 Sq Ft	8 Units 1,280 Sq Ft	1 Unit 960 Sq Ft	2,000 Sq Ft	3 Units 480 Sq Ft	1 Unit 640 Sq Ft	3 Units 960 Sq Ft	1 Unit 40' 1 Unit 20' 480 Sq Ft	4 Units 1,920 Sq Ft	8 Modules 432 Sq Ft
1500	150 Units 24,000 Sq Ft	19 Units 3,040 Sq Ft	9 Units 1,440 Sq Ft	2 Units 1,920 Sq Ft	2,500 Sq Ft	4 Units 640 Sq Ft	1 Unit 640 Sq Ft	4 Units 1,280 Sq Ft	1 Unit 40' 1 Unit 20' 480 Sq Ft	4 Units 1,920 Sq Ft	10 Modules 540 Sq Ft
1800	180 Units 28,800 Sq Ft	23 Units 3,680 Sq Ft	11 Units 1,760 Sq Ft	2 Units 1,920 Sq Ft	3,000 Sq Ft	5 Units 800 Sq Ft	1 Unit 640 Sq Ft	4 Unit 1280 Sq Ft	2 Units 40' 640 Sq Ft	5 Units 2,400 Sq Ft	11 Modules 594 Sq Ft

TABLE VI

PERSONNEL REQUIREMENTS[15,16]
(Officer/Enlisted)

	EMPLOYMENT CASE					
	1	4,7	2	5,8	3	6,9
Squadron (Incl. IMA)	10/100	10/100	35/256	35/256	70/512	70/512
Base Support						
Med (USN)	0/1	0/1	1/3	1/3	2/6	2/6
Dental (USN)	0/0	0/0	0/0	0/0	1/4	1/4
Ecclesiastical Svcs.	0/0	0/0	0/0	0/0	1/1	1/1
Comm/Comm Repair	0/4	0/4	0/8	0/8	1/20	1/20
Food Svcs.	0/4	0/4	0/6	0/6	0/12	0/12
Weather Svc.	0/0	0/1	0/0	0/4	0/0	0/4
Launch/Recovery	0/2	0/2	0/4	0/4	0/6	0/6
Crash/Rescue	0/4	0/4	0/10	0/10	1/15	0/15
Bulk Fuel	0/0	0/4	0/0	0/6	0/0	0/10
Utilities/Engr	0/6	0/6	0/10	0/10	0/15	0/15
Air Traffic Control	0/0	0/4	0/0	1/10	0/0	1/10
Postal	0/1	0/2	0/2	0/4	0/6	0/6
Exchange	0/1	0/1	0/3	0/3	0/6	0/6
Disbursing	0/0	0/0	0/0	0/0	0/0	1/4
Group Staff	0/0	0/0	0/0	0/0	4/10	4/10
TOTALS	10/123	10/133	36/302	37/324	79/613	81/641

of the airplane. Historically, however, while specific items of equipment change, the same building blocks of the aircraft maintenance program remain quite similar from one aircraft model to its successor. Therefore, the space requirements outlined herein should be reasonably accurate.

Maintenance space requirements for each employment mode are shown in Table VI and are broken down into organizational maintenance activity (OMA) and intermediate maintenance activity (IMA) spaces. The numbers shown indicate the number of vans or containers 8x8x20 feet required for each case. Under many conditions, it will not be practicable to power up and operate many of these spaces; e.g., the IMA vans would probably not be required for cases 1, 2 or 3. In other cases, the IMA may be operable aboard only one of a number of ships in convoy. Since sea transportation would, in any case, probably be the cheapest method of transport (as well as retaining unit integrity), the full maintenance suite is included in embarkation requirements. Also included in Table VII are storage requirements for supplies for both aviation peculiar and ordinary Marine Corps supply support of the embarked unit.[17]

TABLE VII

8x8x20 Ft. CONTAINER REQUIREMENTS FOR
AIRCRAFT MAINTENANCE SPACES AND SUPPLY STORAGE

Employment Case	OMA	IMA	SUPPLY	TOTAL
1, 4, 7	4	4	2	10
2, 5, 8	8	12	5	25
3, 6, 9	18	12	10	40

Command, Control, and Communications (C^3)

The embarked aviation units must provide their own communications links to other military agencies. In view of the limited sensor capability, most emphasis must be placed on the ability to receive timely operational and tactical information. Real time tactical control of aircraft would probably require excessive shipboard equipment, and is not considered to be a realistic approach to the C^3 problem.

The Landing Force Integrated Communications System (LFICS) and the Tactical Combat Operations (TCO) system offer a potential solution. This combination could provide interface with Navy Tactical Data System (NTDS) equipped ships enroute and the Marine Air-Ground Intelligence System (MAGIS) and Marine Integrated Fire and Air Support System (MIFASS) in the AOA. Such a system could provide intelligence information for briefing and mission planning, current situation displays, operation plan/order transmission,

and real time communications such as launch orders. The equipments are planned to be lightweight, portable, and have low power requirements.[18] One C^3 MCESS shelter is included in this study for all employment cases except 6 and 9, for which two shelters are included.

Electrical Power Requirements

In most cases, it will be desirable for the embarked unit to be independent of the ship's electrical system. Expeditionary diesel powered generators are already in the Marine Corps inventory to provide power for aircraft maintenance purposes. Generators to support the MCESS modules are under study. These generators should be compatible with installation of a convenient weather deck, and, if so designed, can be operated on aircraft jet fuel.

Consumables

Rates of expenditure of all aircraft consumables will, of course, vary will the operational scenario. For the purposes of this study, arbitrary numbers have been chosen as follows:

a. Sortie distribution: 75% air-to-ground, 15% air-to-air, 10% miscellaneous (maintenance test, ferry, etc.)

b. Fuel consumption: 800 gallons (5200 lbs) per sortie

c. Liquid oxygen: 1 liter per sortie plus one liter per day per aircraft boiloff

d. Ordnance:

(1) Air-to-Ground Sortie - 6 MK-82 bombs

AND EITHER

(a) 4 Rockeye or equivalent cluster weapons

(50% each) OR

(b) 2 Walleye or equivalent weapons

NOTE: All sorties include: 1000 rounds 20mm ammunition

(2) Air-to-Air Sortie - 2 AIM-9 or equivalent type missiles

AND

2 AIM-7 or equivalent type missiles

AND

1000 rounds 20mm ammunition

e. Sortie rate: 4 per day per airplane maximum

f. Food: 3 meals per man per day

g. Water: 40 gallons per man per day

Aviation Fuel

Fuel for embarked airplanes presents what is probably the most challenging logistic problem for this entire concept. The sheer amount of fuel required calls for a great deal of consideration, and could prevent the tactical aircraft operating from merchant ships from ever achieving their full potential sortie and firepower delivery rate. For the sortie

requirements previously stated, the following amounts of fuel may be required daily:

a. Cases 4 and 7: 19,200 gallons

b. Cases 5 and 8: 64,000 gallons

c. Cases 6 and 9: 128,000 gallons

Of the ships investigated, only the Maine class RO/RO has internal storage for liquid cargo, and only 694 tons (approximately 214,000 gallons). On all ships, bunker fuel tanks could be isolated from the ship's main fuel system and used for aviation fuel storage, but this method would require extensive piping changes, time consuming flushing, purging, and cleaning during embarkation, and could reduce ship range performance to an unacceptable degree.

One possible solution of fuel requirements is through the use of container tanks (often called liquid containers). These tanks, designed to carry hazardous and non-hazardous liquid cargo, are available for purchase or rental from a number of U.S. firms. A typical 8x8x20 ft. tank container, with a capacity of approximately 5,000 gallons, is shown in Figure 6. As an example, the container shown in Figure 6 may be purchased for under $20,000 or rented for $10 to $20 per day.[19] Container tank requirements for five days' operations based on these typical containers, would be:

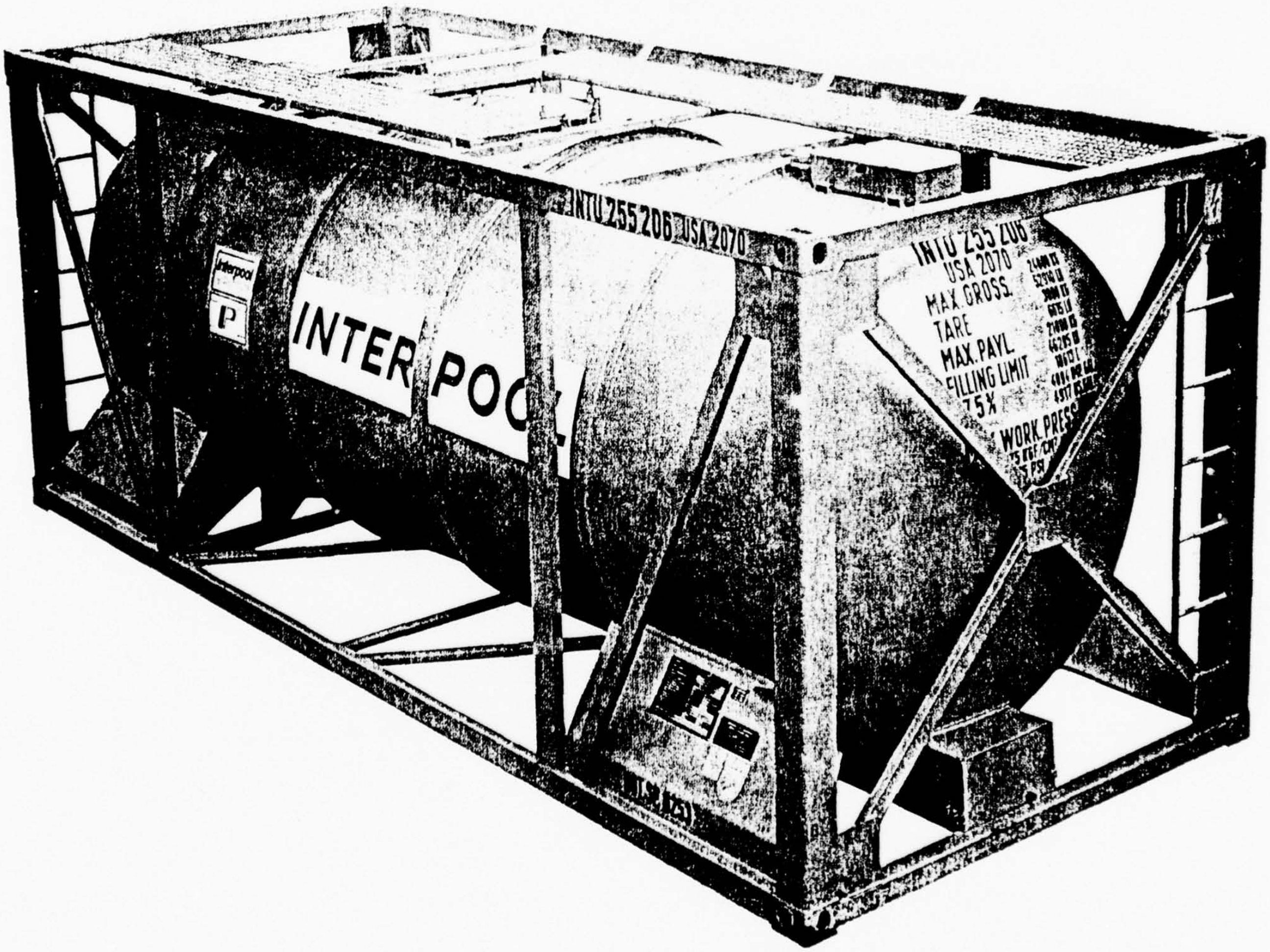
a. Cases 4 and 7: 20

b. Cases 5 and 8: 64

c. Cases 6 and 9: 128

FIGURE 6

CONTAINER TANK



The replacement for the tactical airfield fuel dispensing system (TAFDS) will be a series of six bladders in an 8x8x20 ft. rigid frame known as a SIX-CON. The SIX-CON can be configured with five bladders and a pump/filter unit which provides for delivery directly to the aircraft. Two experimental versions of the pump unit are under consideration, one diesel-powered and one gasoline engine powered. The diesel unit, while heavier and more expensive, has two distinct advantages: It is capable of high delivery pressure and flow rate required for refueling tactical aircraft (approximately 250 vice 100 gpm) and, in addition, can be run on jet fuel. This second feature eliminates the requirement for a separate supply of gasoline, and should be superior from a support and safety viewpoint.

Although merchant ships have occasionally refueled underway from Navy oilers, it is not a common procedure. In order to replenish either bunker fuel or jet fuel underway, some ship modifications will be required and some training should be conducted. In view of the quantity of fuel required and the precision with which containers must be positioned, vertical replenishment of liquid containers by helicopter does not appear to be feasible.

One possible source of refueling would be a towed, semi-submersible bladder. The bladder could be towed to the AOA or carried empty and fueled from an oiler. The bladder,

with a tug/barge as a tender, could be positioned in a semi-stationery location for occasional refueling operations. As an example of available assets, one such bladder, manufactured under the trade name of Dracone, is a flexible towable container constructed from synthetic rubber-coated nylon fabric. Dracone is manufactured in several sizes up to 290,000 gallons, towable at 6 kts, and smaller sizes which can be towed at speeds up to 10 kts.[20,21]

Regardless of the refueling method, however, a five-day supply of fuel for embarked airplanes appears to be prudent.

Aviation Ordnance

The exact type of ordnance to be carried on each sortie is, at best, educated conjecture on the part of the writer. It is probably safe to assume, however, that for the purpose of computing storage and handling requirements, a mixture of free-fall bombs (possibly laser guided), cluster weapons, terminally guided glide bombs or missiles, air-to-air missiles, and machine gun ammunition--using weight and cube figures for current munitions--should be sufficiently accurate. Under these conditions, with the previously stated sortie rates, potential daily requirements are:

a. Six plane detachment (cases 4 and 7): 223,080 lbs/ 5,245 cf.

b. Twenty plane squadron (cases 5 and 8): 743,600 lbs/ 17,495 cf.

c. Two twenty plane squadrons (cases 6 and 9): 1,487,187 lbs/35,000 cf.[22]

If one further assumes that five days of flight operations will be conducted prior to movement ashore or resupply, then the shipboard storage and handling requirements become:

a. Cases 4 and 7: 1,115,400 lbs/26,225 cf

b. Cases 5 and 8: 3,718,000 lbs/87,475 cf

c. Cases 6 and 9: 7,435,990 lbs/175,000 cf

An attractive method of loading and storage would be to use commerically available standard size containers, 8x8x20 ft. or 8x8x40 ft. Both are readily available for either sale or lease by a number of U.S. firms. The smaller containers typically hold 1,100 cubic feet and 40,000 lbs. cargo; the 40 ft. containers are typically rated at 2,300 cubic feet and 60,000 lbs. Container requirements for five days' ordnance requirements would be:

	20 ft Containers	40 ft Containers
a. Cases 4 and 7:	28	19
b. Cases 4 and 8:	93	62
c. Cases 6 and 9:	186	124

In addition to the improved embarkation capability, containerization should also ease some problems of ordnance storage compatibility by physically separating non-compatible ordnance in containers aboard ship.

Ordnance movement aboard ship may require some special installation. Aboard a roll on-roll off (RO/RO) ship, ramps

between decks provide easy movement by fork lift, trailer or SATS-loader. Aboard a cellular container ship, if ordnance is not stored on the level where it is to be loaded, then provisions for an elevator or hoist must be provided if expeditious handling is to be accomplished. Furthermore, storage of these amounts of heavy ordnance near the upper levels where it will be loaded aboard aircraft could adversely affect ship stability.

Liquid Oxygen (LOX)

During 1974-75, six AV-8A airplanes were deployed aboard an LPH for a six-month cruise. In order to avoid the installation of a LOX plant, a full 500 gallon LOX trailer was embarked prior to the cruise. This trailer was refilled ashore (transported by CH-53) twice during the cruise, although one refill probably would have sufficed. This procedure would easily accomodate the LOX requirements summarized in Table VIII.

New technology will probably eliminate the requirement for LOX. The on board oxygen generating system (OBOGS) is a jet engine accessory which chemically produces a breathable 95% oxygen whenever the engine is running. This system will be test flown during 1978, and should eventually be installed in all tactical Navy/Marine aircraft.

TABLE VIII

DAILY LIQUID OXYGEN REQUIREMENTS
By Employment Case
(U.S. Gallons)

1	2	3
1.5	5	10
4	**5**	**6**
1.5 in transit 6 in AOA	5 in transit 25 in AOA	10 in transit 50 in AOA
7	**8**	**9**
6	25	50

Food and Water

The refrigeration storage units and dry storage units listed in Table V will provide capability to embark sufficient food for a typical voyage. If required, additional commerical refrigerated containers may be embarked and run from ship electrical power. With the potential food storage capacity inherent in the candidate ships, it is quite likely that other Navy ships in company will be receiving frozen foods from the merchant ship.

The water purification units listed in Table V are each capable of producing 600 gallons per hour of fresh water (from sea water) by a reverse osmosis process. In addition, in the event of a casualty, all ships investigated had an excess evaporator capacity of at least 6,000 gallons per day.

Organizational Property

Some organizational property not required enroute must be embarked for use once the aviation unit has moved ashore. Since a great number of these items currently carried are such expeditionary items as tentage, field kitchens, etc., which will be replaced by MCESS shelters, embarkation requirements for such items will be drastically reduced. In the absence of precise data, it is estimated that approximately one-third of existing weight and cube requirements must be embarked over and above that carried in the MCESS shelters. One-third of the Mechanized Embarkation Data System (MEDS) requirements for an AV-8 squadron or detachment "B" yields the following additional 20 foot container requirements.

Cases 1, 4, 7:	3
Cases 2, 5, 8:	7
Cases 3, 6, 9:	14

Total Container Requirements

A summation of the container requirements in twenty-foot equivalent units (TEU) for aircraft unit working spaces, hotel facilities, fuel, ordnance, command and control, and additional organizational property is, by case:

Employment Case

	Det (1)	Sqdn (2)	Two Sqdn (3)
Transportation	41	85	153
	(4)	(5)	(6)
Ltd. Ops.	90	243	469
	(7)	(8)	(9)
Full Scale Ops	90	243	469

Realistically, it will be extremely difficult to generate the sortie rates used for the computation of fuel and ordnance requirements. The primary restriction will be the movement of aircraft between the flight deck and lower "hangar" decks. This problem will be least severe with cases 4 and 7, where most airplanes may be kept on the flight deck, and will increase in magnitude with increasing numbers of airplanes. Therefore, the estimates for fuel and ordnance are probably on the high side. Careful study of a specific ship installation and aircraft load would provide more accurate estimates.

CHAPTER V

CANDIDATE SHIPS

In the search for candidate ships little attempt was made to identify suitable ships per se, although some were observed which could be configured for use now. The objective was rather to identify those features of contemporary ships which are desirable or undesirable for VSTOL aircraft operations. This approach was used since, because of the time frame involved, few of the ships studied could be considered "modern" or "contemporary" by the turn of the century. Through this approach, it was possible to identify a number of national defense features which can, with minimal effort or expenditure of shipbuilding subsidies, can be designed into new construction ships to make them much more suitable for the purpose under study without compromising their economic viability as commercial ships.

Future Merchant Fleet

Some interviews with knowledgeable individuals in the maritime industry were useful in predicting the character of the future U.S. merchant fleet.[1-7] Consensus is that the non-self-sustaining cellular containership will continue to be the most common ship design. The most economical size is predicted to be 900-1000 feet length overall with a container capacity of about 3000 twenty-foot equivalent units

(TEU). Roll On/roll Off (RO/RO) ships will continue to be constructed and operated in significant numbers, but only for specialized cargo which cannot readily be containerized (automobiles, heavy machinery or outsize cargo, for example) and for service to ports without the huge gantry cranes required for container loading and offloading. Because of their lower cargo density, RO/ROs are less economical than containerships, and therefore less attractive to operate despite the above advantages. The barge carrier such as LASH or SEABEE designs will also continue to operate, but will be advantageous only for service to those areas without deep water port facilities; e.g., locations up a river or canal from the ocean.

The most economical propulsion system is the single-screw, steam turbine design (approximately 17-18% more efficient than a twin-screw plant) using bunker fuel as an energy source. Slow speed diesels may be used in the 35 to 40 thousand horsepower range, suitable for a 20 kt, 2000 TEU ship. Although a few ships will have a 30 kt or greater speed capability, economic factors such as fuel consumption and cargo value will probably dictate typical ship design speeds of 23 to 26 kts. The desire to have a Panama Canal transit capability will limit maximum beam dimension to 105 ft. 6 in.

Ship Criteria[8,9]

Although a number of foreign flag ships were marginally attractive, only U.S. flag ships were examined. This self-imposed criterion served to restrict the study to a manageable size and provided easier access to information and ship visit arrangements. Also, for actual employment, U.S. flag ships are the most readily available for wartime operations.

With only two exceptions, ships examined were of post-1970 construction. There appeared to be a watershed of ship design philosophy in the late 1960s as shippers turned to higher speed vessels especially designed for containerization and intermodal transportation--as opposed to the older breakbulk cargo ships. These newer ships are considerably more representative of circa 2000 ships than were previous designs. All ships studied have published cruising speeds of 20 knots or greater; one class was capable of 33 knots.

An obvious requirement for any candidate ship was that it have sufficient container capacity to accomodate the previously described shipboard requirements and a large relatively open topside area free of obstructions which could interfere with flight operations. These two requirements eliminated combination breakbulk/containerships (also called partial containerships) or self-sustaining containerships because of the massive masts and booms associated with these types. The container requirement eliminated

oilers and tankers although their fuel capacity made them tempting candidates. Although no specific size criteria were established for the study, it was desired that the ship be large enough to provide a stable platform at sea. As it turned out, the smallest ship studied was 661 feet overall and over 15,000 tons gross displacement.

Three general ship types were studied: the cellular containership, the RO/RO, and the SEABEE barge carrier. A total of ten classes (six containership, three RO/RO, and one SEABEE) representing 54 bottoms were examined. This number covers 17% of the total U.S. flag dry cargo fleet and 36% of the U.S. flag containership fleet. Of these ships, seven classes (four container, two RO/RO, and one SEABEE) were actually visited and their crew members interviewed. Specific ship characteristics are shown in Appendix A, Figures 7 through 17.

Common Characteristics

All ships examined had adequate unsecure communications to handle routine administrative ship's traffic. High frequency and very high frequency (for port control) equipment were most common, with an occasional satellite communication (voice) capability. Additional tactical communications equipment would be required for embarked units, and is discussed under "Command and Control." All ships had excellent navigation equipment, with LORAN C backed up by celestial

being the most common. Some ships had satellite navigation equipment installed which was reported to be reliable, easy to use, and accurate to within 0.01 nautical miles. All ships had excellent surface search radar--often two sets--but none had an air search capability. All ships had the capability to carry refrigerated containers to provide abundant foodstuffs for embarked personnel. Weather facsimile receivers were installed, but probably would not provide sufficient information for aviation weather forecasting.

Deck Motion

None of the experts interviewed was able to provide precise data on ship pitch and roll. All agreed, however, that in any sea condition, roll amplitude was drastically affected by the vertical distribution of the load. Relative direction of the sea was also identified as an important factor, with the most critical condition being a quartering sea. A fairly consistent qualitative opinion was that, under routine steaming conditions, this size ship, properly loaded, experiences "less than 10 degrees of roll during 95% of a typical voyage," although 35° rolls in storms were described.*

Typical design criteria for containers and container restraint systems provide for 35 degrees of roll, 13 second

*Many of the vessels studied have passive (flume tank) stabilization systems. None are equipped with vane stabilization.

period, and 1.8 lateral "g." Two incidents of container loss or damage were reported in this admittedly small survey, both to forwardmost containers on the weather deck. In one case, a container was caved in by a large wave in a North Atlantic storm; in the other case a container was lost over the side in a North Pacific storm. Both mishaps were the result of structural failures of the containers, not the shipboard restraint system.

All ships studied except Sea Land's SL-7 class have single screw propulsion systems. Crew members were enthusiastic about the single-screw steam turbine plant reliability, although one of the ships was visited in a shipyard after having been towed in 200 miles following a reduction gear failure. This was described as an aberration; no further attempt was made to gather additional failure data.

Cellular Containership

The cellular containership is by far the most common carrier, and is predicted to remain so for the foreseeable future. Cellular containerships are characterized by a series of holds into which containers of a standard dimension are lowered along vertical rails which provide horizontal positioning and restraint. Typical holds are capable of accomodating a depth of six containers in the

hold and as many as four layers on top of the hatch covers on the main deck.

All containerships studied were non-self-sustaining; that is, a gantry crane, permanently installed on a pier is required for expeditious load and offload. Under good conditions, using two cranes, a loading or offloading rate of 50 to 55 containers per hour can be sustained. Only the Pacesetter class (American President Lines) has the supporting structure to permit shipboard crane installation, although no tailored cranes are installed or even in existence. Installation of a Bay City-type crane on most ships probably could be accomplished, but only a detailed engineering study could determine the required structural ship modifications. Offload of main deck containers could probably be accomplished by properly configured heavy lift helicopters. Onload of main deck containers could possibly be performed by helicopter, but this evolution would require running gear to precisely position the containers on the interbox units (IBU) or else exceptional pilot skill and ideal deck and wind conditions. Helicopter offload of containers from the holds would be quite demanding; helicopter loading of hold containers, would, in the author's judgment be impossible.

Since much of the cargo for the assault follow-on echelon (AFOE) is already programmed for transportation via containers, the problem of offloading in the AOA is already

receiving priority attention. The container offloading and transfer system (COTS) shows promise for solving the off-load problem, and will still be required whether or not a VSTOL aircraft unit is added to the equation.

Compatability of container sizes is most critical aboard cellular containerships. The most common size is 8x8x40 feet, followed by 8x8x20 feet. Matson Lines uses a 24-foot container in their essentially closed-loop West Coast to Hawaii runs. Sea Land uses a 35-foot container, but their ships are also capable of handling some 40-foot containers.

Because of the large number of containers which can be carried by a cellular containership, there will be a significant excess capacity after embarkation of the aircraft unit. This capacity can be used for, among other things, transportation of assets normally found in the AFOE.

Containerships are the best compartmented of any type studied. They typically have four or five discrete compartments below decks, separated by water tight athwartship bulkheads. The SL-7 class has nine watertight compartments.

Of all ships studied, containerships will require the most extensive and elaborate installation for VSTOL operations. Since there are no provisions for movement of heavy cargo once it is embarked, and only a few (6-8) aircraft spots would be available topside, some type of aircraft elevator or ramp would be required if more than this number were to be carried. In addition, unless ordnance and other

heavy items were stored on the level where they are to be loaded, an elevator or other lift machinery must be installed in the hold where these items are stored. Sketches of a possible installation are shown in Appendix B.

Roll On/Roll Off Ships (RO/RO)

RO/RO ships offer the advantage of ramps for movement of equipment between decks while enroute. The large, open decks provide easy access to containers and equipment, and remind one of the hangar deck aboard an aircraft carrier. Unfortunately, the ramps aboard RO/ROs visited were not large enough to accomodate any of the aircraft listed in Table IV. Ramp widths varied from 17 to 24 feet; heights ranged from 10 to 13 feet. The "Maine" class has a ramp from the main deck to a level 10 feet above the main deck. It would, of course, be possible to install a ramp or elevator to move aircraft from the main (weather) deck to the "flight" deck atop two layers of containers, but only with increased installation time and expense. Such a scheme would permit use of the main deck as a hangar deck with the flight deck two container layers above.

The RO/RO can also be loaded and offloaded at pierside without gantry cranes, although gantry cranes can be used to expedite load/offload of topside containers. Normally, however, containers on running gear are moved via the internal and external ramps. At least one RO/RO, operating

on the northeast Pacific route, has heated weather decks for ice prevention.

Although the RO/RO offers some advantages, it has two drawbacks. There are fewer of them, and their lower cargo density means that a higher proportion of available capacity must be devoted to the embarked aircraft unit; therefore a proportionately smaller share is available for AFOE assets.

SEABEE Barge Carrier

The SEABEE is designed to transport large barges (98x35x17 feet). The barges are positioned on wheeled transporters placed on a large submersible stern elevator, then raised to a level even with one of three decks. The barges are rolled forward onto one of the three decks for transit. Containers may be secured to the top of the barges on the upper deck (either before loading the barges or after they are aboard using a pierside gantry crane). Using only the elevator, the SEABEE can be completely loaded or unloaded of barges in approximately 20 hours. When fully loaded with 38 barges, the SEABEE can simultaneously carry up to 160 8x8x40-foot containers on the upper decks. Up to 1800 TEU container capacity is available if no barges are carried.

An attractive feature of the SEABEE for purposes of this study is the 2000 ton capacity stern elevator which would facilitate the movement of aircraft, ordnance, or

other heavy loads between decks. By building a flight deck on top of two layers of containers and one layer of barges on the upper deck, the entire second (main) deck could be used as a hangar deck. Two main "aisles" over 35 feet wide extend the full length of the second deck. Pedestals, protruding approximately two feet above the deck would require installation of a deck on top of them. Forty or more AV-8 size aircraft could easily be accomodated on the second deck, with ready access to over half of them. A small "pack" of maintenance aircraft could be stowed well forward on the second deck, and the elevator could be used for inter-deck movement. A platform (which could consist of a barge and two layers of containers) or ramp would be required to get aircraft to the level of the "flight" deck. Since the third (lower) deck is occasionally subject to flooding, no cargo other than barge enclosed items could be placed there. Cargo stored in lower deck barges would not be readily accessible enroute; however, if some barges could be configured to carry approximately 300,000 gallons of jet fuel each, the aircraft fuel storage problem would be solved.

Two flight deck layouts are immediately obvious. One would be to angle the takeoff axis approximately 11 degrees to clear the bridge. The other, less desirable, would be to launch aircraft aft, which would probably require the ship to reduce speed or turn out of the wind. Approximately

80 feet athwartship dimension is available between the two amidship stacks.

According to the ship's master, the SEABEE has the best ride of any ship examined. With a passive (oil) stabilization system, 10-foot seas and force 5 winds (21-25 kt) from any direction result in ± 5 degrees of roll.

The SEABEE is capable of her 20 knot design speed up to approximately 35 feet of draft. At her full displacement (39 feet draft) whe will only make approximately 18.5 knots. An additional disadvantage is the limited number (three) in service. Also, failure of the elevator could preclude movement of aircraft between decks and, depending upon the position at failure, could even preclude offload of second deck assets.

CHAPTER VI

SHIP INSTALLATIONS

At least one preliminary study has been completed in the area of ship installations. Fairey Engineering Limited has produced preliminary designs for the construction of a flight deck atop the above-deck containers.[1] The Fairey scheme utilizes the medium girder bridge (MGB)--a standard NATO military bridge already existing in large numbers[2]--as a flight deck which also could include a "ski-jump." The bridges and supporting structure are installed on top of a tunnel created by the outboard rows of containers. The area under the bridges serves as a hangar deck; the outboard rows of containers are available for shop space, fuel, or other uses. Another deck on top of the main deck hatch covers is required, as is some type of membrane to make the hangar deck weatherproof. Sample sketches and photographs of a scale model containership installation are shown in Appendix B, Figures 18 through 22.

For aircraft movement between decks, only the SEABEE ship has an integral elevator. Ramps on existing RO-RO ships will not accomodate any existing or proposed VSTOL aircraft. For containerships, the Fairey design envisions a 36 by 48-foot elevator which could move both aircraft and equipment. It is this author's opinion that, aboard

large containerships, a ramp system may be preferable to an elevator. A ramp would offer the advantages of reliability, low cost, and ease of damage repair. The universal handling vehicle, under development by the Naval Air Systems Command, will be required to tow an F-14 up or down a 10 degrees ramp, and should handle a smaller airplane with ease.[3]

Any installation should be designed so as to minimize ship alternation requirements. This approach would serve the twin purposes of expediting installation while making the entire concept more palatable to commercial ship owners.

One national defense feature which merits serious consideration is the enlargement of ramps of new construction RO/RO ships so as to accomodate new VSTOL airplanes. Such changes should be planned in close cooperation with aircraft designers in order for beneficial compromises to be realized. The Chief of Naval Operations (OP-405) is the DOD agency responsible for national defense feature coordination with the Maritime Administration in accordance with the current OPNAVINST 4700.13.[4]

In order for this concept to be viable, the installation scheme should be as standardized as possible among the candidate ships. Since there is currently no good method of predicting what specific ships might be available, the kit should be readily adaptable to as many classes of ships as possible. In this regard, adapter structures will be

required to accomodate 20 and 40-foot containers aboard ships designed, for example, for 24 or 35-foot containers. Also, a problem for the SL-18 class ship is the 20-foot high buttresses between hatches which may require a unique installation design.

It appears that design of a ship installation to accomodate 20 aircraft aboard a containership is possible, except aboard the SL-18 class where the buttresses between hatches may preclude a "hangar deck."[5] The SL-18 may be restricted to carriage of approximately six aircraft on the "flight deck" only. Unless larger ramps (or smaller airplanes) permit movement between decks, RO/RO ships may also be limited to a smaller number of aircraft, using topside containers as structural support.

The expense and effort required to configure a merchant ship will obviously limit the number of installations available. Economic tradeoffs will probably show that such installation--and the USMC support personnel required--would not be economically viable for only six airplanes. On the other hand, the embarkation of as many as 40 airplanes would probably constitute an excessive survivability risk except in the most permissive environments. Therefore, the most viable employment concept will probably call for appromimately 20 airplanes per ship.

CHAPTER VII

MISCELLANEOUS CONSIDERATIONS

Survivability

Two features combine to reduce the combat survivability of a merchant ship from that of a Navy combatant ship: ship design and reduced manning. The reduced manning (typically 38-42 men) does not provide sufficient manpower for ship operations and extensive damage control efforts simultaneously. Augmentation by embarked troops or external personnel may be required. Ship design factors include:

a. Single power plant and propeller, except in the case of the SL-7 containership.

b. Less redundancy in most systems, including internal communications.

c. No armor plating.

d. No defensive weapons.

e. Less compartmentation.

It is worth noting that a number of U.S. Navy ships, including the LCC, LPH, LPA, LKA, and all frigates share the single-screw shortcoming of the typical merchant ship. A single boiler casualty aboard a merchant ship could, however, cause a loss of firefighting and survival capability as well as loss of propulsion.

If the merchant ship were in company with combatant ships, she could stay under the protective umbrella surrounding

the convoy. For close in air/missile defense, embarkation of the gun or missile system to be used by the Landing Force ashore could provide a primitive system. Admittedly, such an improvisation would not have the extensive sensors and fire control system of a combatant ship, but would be better than no close-in defense at all.

A Navy ship is required to survive a hull opening below the water line 12.5% of the length of the ship between perpendiculars. A U.S. merchant ship, on the other hand, is only required to have sufficient stability to remain afloat with one compartment (of, typically, four or five) flooded.[1] One opening spanning a watertight bulkhead would, of course, flood two holds. The SL-7 class is an exception, in that it can remain afloat and upright with up to four of its nine compartments flooded.[2] Watertight containers in the holds of a containership would reduce the volume of water which would be admitted, but would probably only provide marginal additional stability. Empty or inert cargo containers surrounding explosive, volatile, or valuable cargo could reduce the consequences of a penetrating hit.

In summary, although merchant ships are more vulnerable to combat damage than are many Navy combatants there are some relatively simple steps which could increase their survivability somewhat. Judicious spread loading of assets can reduce the impact of a single loss or delay.

Legal Considerations

Once chartered by the Military Sealift Command, acting for the U.S. Navy, the ship may be placed under the operational control of a fleet commander or major subordinate commander. The ship's master would then be legally responsible to an operational Navy commander for the employment of his ship. The master would be responsible, in turn, for performance and discipline of his civilian crew. The commanding officer of the embarked unit would retain disciplinary authority over embarked military personnel.

Although still appearing as a merchant ship, there will certainly be a loss of innocence by the merchantman as a result of combat flight operations from her deck. Possible classifications under maritime law are "auxiliary cruiser," "armed merchantman," "converted merchantman," or "privileged combatant." However, she would probably not legally be categorized as a warship under the classic definition. Article 8 of the Convention of the High Seas (1958) states that a warship must:

a. Belong to the forces of the naval state.

b. Bear external markings distinguishing warships of its nationality.

c. Be under command of an officer, duly commissioned by the government, whose name appears on the navy lift.

d. Be manned by a crew under regular navy discipline.

Since offensive combat operations will be conducted by the aircraft launched from the ship, the possibility of some civilian crew members being open to war crimes charges should be explored. Preliminary inquiries indicate that they are not violating a law of war and are providing no deception as to their mission or purpose. They would probably have the status of "civilians accompanying armed forces in a combat area," particularly if the merchant ship were in a convoy of combatant ships and, therefore, susceptible to enemy attack. If captured, they should have prisoner of war status. The desirability of enlisting crew members in the Naval Reserve prior to sailing may be worth investigating.[3,4,5]

Maritime Safety Considerations

Interviews with knowledgeable Coast Guard officials did not reveal any major safety considerations which could, in themselves, preclude the operation of VSTOL aircraft from merchant ships. No definite opinion or decision could be given until a particular loading plan for a particular ship is presented. It appears, however, that the concept can be made compatible with existing safety directives. High explosives must be stowed in a hold separate from all other cargo, and fuel containers "should" be stored topside, although below deck storage could possibly be approved. Life rafts and survival gear must be provided for embarked personnel. The structural modifications or installations

must be approved by the Coast Guard, as must the habitability--space, ventilation, sanitary facilities, etc.--of the embarked living modules.[6]

As the design of each installation proceeds, there will undoubtedly be some instances of incompatibility. In these cases, advance requests for waiver should be prepared in accordance with Title 46, United States Code, which states:

> The head of each department or agency responsible for the administration of the navigation and vessel-inspection laws is directed to waive compliance with such laws upon the request of the Secretary of Defense to the extent deemed necessary in the interest of national defense by the Secretary of Defense. The head of such department or agency is authorized to waive compliance with such laws to such extent and in such manner and upon such terms as he may prescribe, either upon his own initiative or upon the written recommendation of the head of any other Government agency, whenever the deems that such action is necessary in the interest of national defense.[7]

Ship Availability

Ships may be obtained via individual charter under the Sealift Readiness Programs or through direct requisition of any U.S. flag ships. Both methods are independent of mobilization, and could be used to obtain as many ships as may be required. Although no time-phased ship availability schedules are available, knowledgeable officials within the U.S. Maritime Administration predicted that ships could probably be made available in U.S. ports faster than assets to be embarked could be staged. A possible exception could be RO/RO or SEABEE ships, which are simply less common than

cellular containerships. Requisition or charter of a large number of ships could disrupt civilian shipping and would be a politically sensitive move.

Competition for ships will include the U.S. Army, which has already identified its requirements for resupply to Europe, and other landing force elements. The number and priority of players will be scenario dependent and will be almost impossible to generalize. Under those scenarios where tactical aviation units must be deployed via merchant ship, they should receive appropriate priority.[8,9]

CHAPTER VIII

CONCLUSIONS

1. Operation of tactical VSTOL aircraft aboard many merchant ships is feasible, provided that some ship facilities are installed.

2. The required installation can be made up predominantly from hardware which is either existing or already under design.

3. Even with required installations, a modified merchant ship will probably not be as effective as a Navy ship designed for aircraft operations.

4. Of the ship types studied, none was ideal, but all possessed many desirable features.

5. Relatively simple national defense features aboard new construction ships combined with some additional VSTOL aircraft design criteria will significantly enhance the operations under study.

6. The most critical factor affecting sortie rate will probably be restricted movement of airplanes between decks.

7. The factor limiting total number of sorties during a cruise will probably be the limited amount of aviation fuel which can be carried aboard ship and the difficulty of fuel resupply.

CHAPTER IX

RECOMMENDATIONS

1. It is recommended that the Chief of Naval Operations form a working group to establish an operational requirement and define hardware for the employment of VSTOL aircraft aboard selected merchant ships. The goal of this working group should be the installation of a prototype kit and the conduct of flight tests at sea. This group should include experts in the fields of:

   a. Ship engineering
   b. VSTOL shipboard operations
   c. VSTOL aircraft design
   d. VSTOL aircraft test and evaluation
   e. Amphibious operations
   f. Shipboard landing aids
   g. Firefighting and damage control
   h. Aircraft maintenance
   i. Aviation fuel handling
   j. Aviation ordnance
   k. Ship habitability
   l. Maritime safety
   m. International law
   n. Sealift mobility
   o. Communications

2. It is further recommended that the working group pay particular attention to determining soundness from an engineering standpoint in order to provide a satisfactory degree of effectiveness, safety, and survivability, and the legality of conducting offensive combat operations from a merchant ship.

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APPENDIX A

SHIP CHARACTERISTICS

FIGURE 7

"LEADER" CLASS CONTAINERSHIP

OWNER: United States Lines	NO. IN SERVICE: 8
DESIGN: C61W	NO. OF PROPELLERS: 1
YEAR CONSTRUCTED: 1953-54	DEADWEIGHT TONS: 15,523
LENGTH OVERALL (FT.): 661	SPEED (KTS): 20.0
BEAM (FT.): 76	RADIUS (NM): 12,000
DRAFT (FT.): 29	CONTAINER CAPACITY: 1009 TEU

FIGURE 8

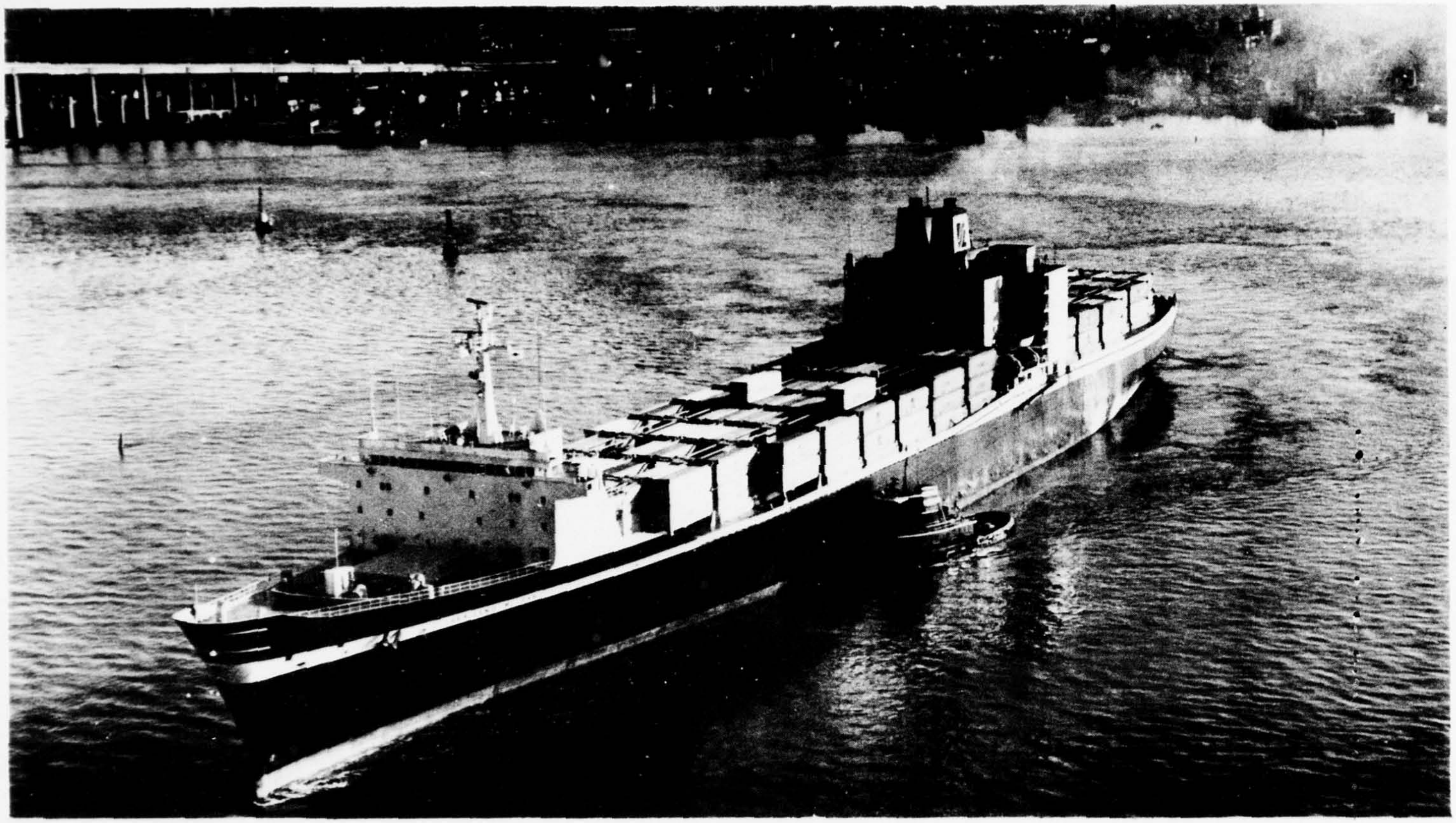
"LANCER" CLASS CONTAINERSHIP

OWNER: United States Lines
DESIGN: C7-S-68
YEAR CONSTRUCTED: 1968-71
LENGTH OVERALL (FT): 705
BEAM (FT): 90
DRAFT (FT): 33

NO. IN SERVICE: 8
NO. OF PROPELLERS: 1
DEADWEIGHT TONS: 20,015
SPEED (KTS): 22.5
RADIUS (NM): 10,000
CONTAINER CAPACITY: 1,330 TEU

FIGURE 9

SL-7 CLASS CONTAINERSHIP



OWNER: Sea-Land Services, Inc.
DESIGN: SL-7
YEAR CONSTRUCTED: 1972-73
LENGTH OVERALL (FT): 947
BEAM (FT): 105
DRAFT (FT): 35

NO. IN SERVICE: 8
NO. OF PROPELLERS: 2
DEADWEIGHT TONS: 27,290
SPEED (KTS): 33.0
RADIUS (NM): 8,000
CONTAINER CAPACITY: 1096 (770-35ft/326-40ft)
102 can be temperature controlled

FIGURE 10

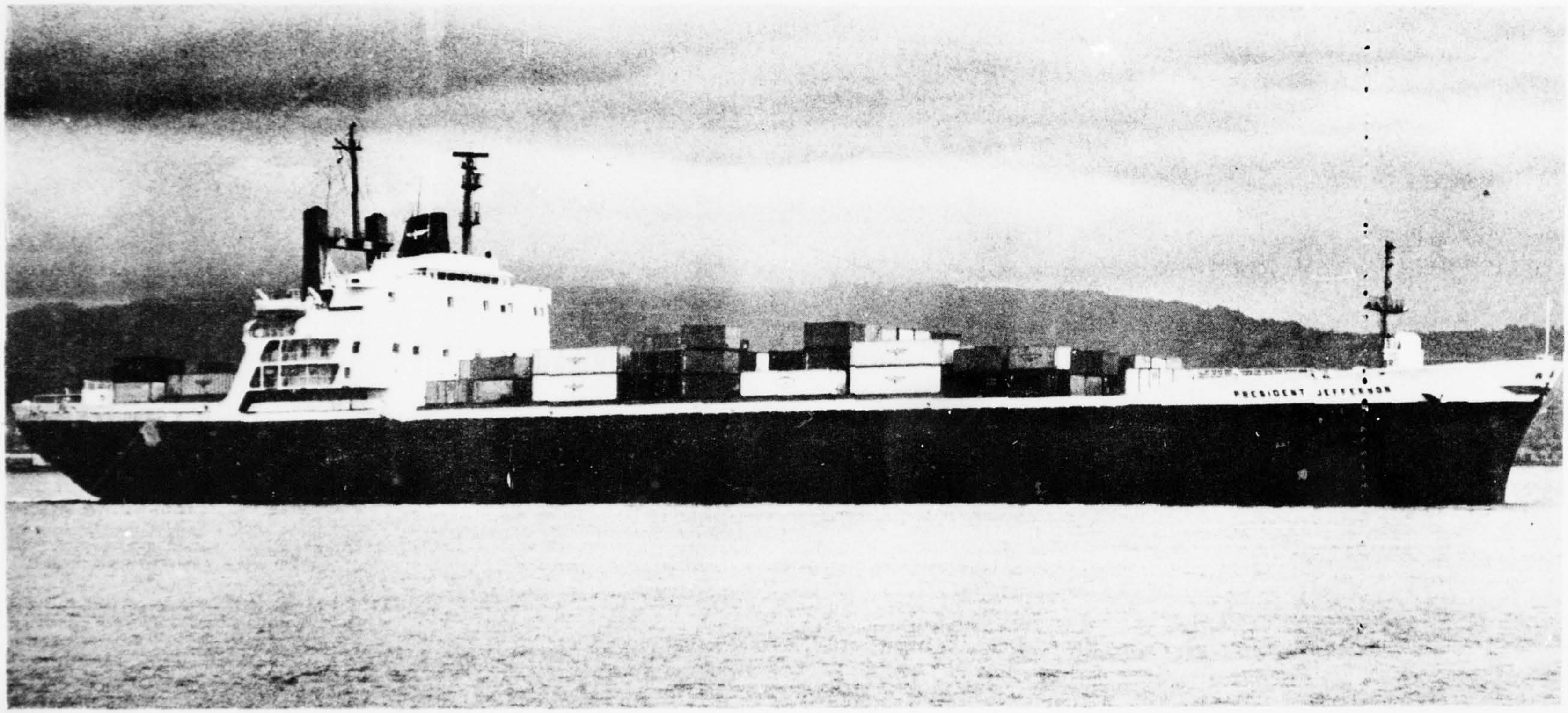
SL-18 CLASS CONTAINERSHIP

OWNER: Sea-Land Services, Inc. Matson Navigation Co.	NO. IN SERVICE: 4 2
DESIGN: C7-S-88	NO. OF PROPELLERS: 1
YEAR CONSTRUCTED: 1970-74	DEADWEIGHT TONS: 26,000 ± 500
LENGTH OVERALL (FT): 721	SPEED (KTS): 23.0
BEAM (FT): 95	RADIUS (NM): 7,000*
DRAFT (FT): 34	CONTAINER CAPACITY: 733 (552-35ft/181-40ft) for Sea-Land ships; 1056 (896-24ft/160-40ft) for Matson ships.

*Approximately 4000 for Sea-Land Economy and Venture.

FIGURE 11

"PACESETTER" CLASS CONTAINERSHIP



OWNER: American President Lines	NO. IN SERVICE: 4
DESIGN: C6-S-85B	NO. OF PROPELLERS: 1
YEAR CONSTRUCTED: 1973-74	DEADWEIGHT TONS: 20,720
LENGTH OVERALL (FT): 669	SPEED (KTS): 23.0
BEAM (FT): 90	RADIUS (NM): 17,000
DRAFT (FT): 33	CONTAINER CAPACITY: 1180 TEU
	68 can be temperature controlled

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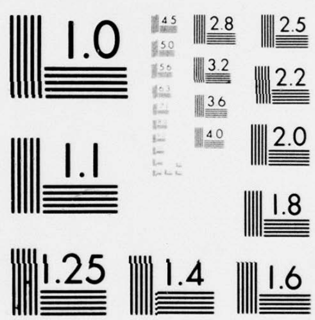


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

FIGURE 12

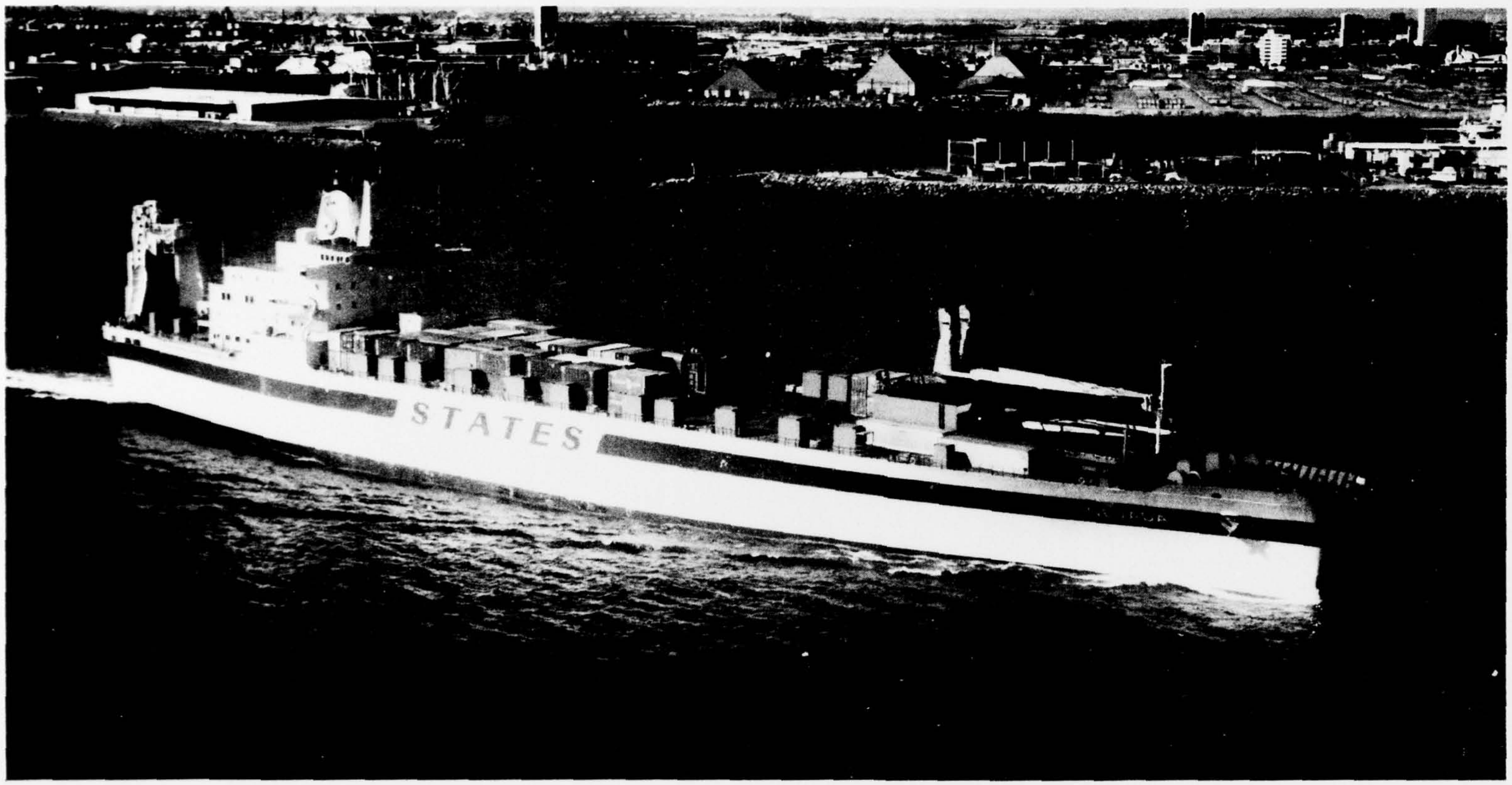
"SEAMASTER" CLASS CONTAINERSHIP

OWNER: American President Lines
DESIGN: C6-S-69C
YEAR CONSTRUCTED: 1967-68
LENGTH OVERALL (FT): 664
BEAM (FT): 82
DRAFT (FT): 31

NO. IN SERVICE: 4
NO. OF PROPELLERS: 1
DEADWEIGHT TONS: 17,600 ± 100
SPEED (KTS); 23.0
RADIUS (NM): 15,000
CONTAINER CAPACITY: 1096 TEU
86 can be temperature controlled

FIGURE 13

"MAINE" CLASS ROLL ON-ROLL OFF (RO-RO)

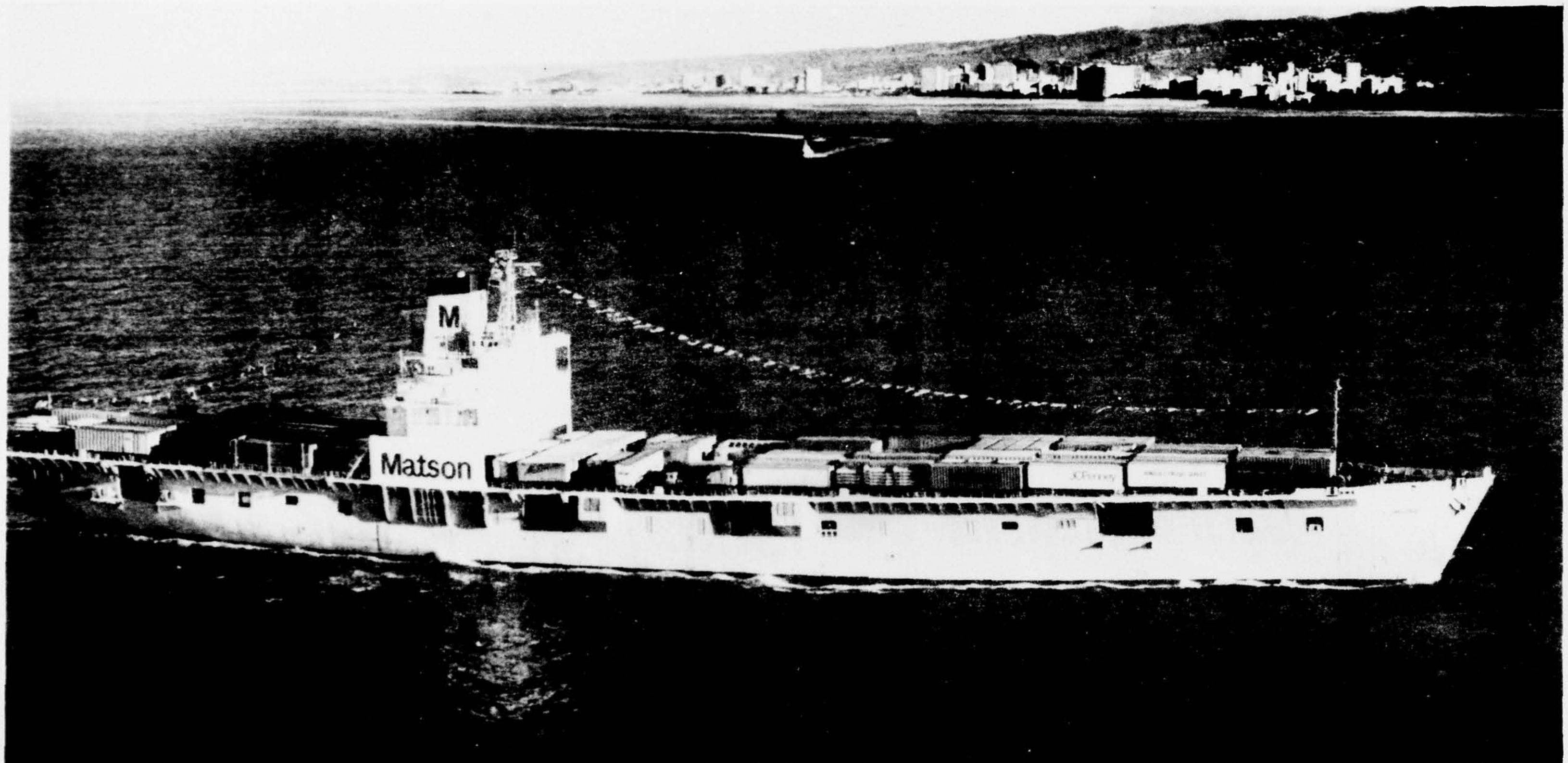


OWNER: States Steamship Co.
DESIGN: C7-S-95
YEAR CONSTRUCTED: 1976-77
LENGTH OVERALL (FT): 684
BEAM (FT): 102
DRAFT (FT): 32

NO. IN SERVICE: 4
NO. OF PROPELLERS: 1
DEADWEIGHT TONS: 19,543
SPEED (KTS); 23.0
RADIUS (NM): 11,000
CONTAINER CAPACITY: 900 TEU plus
5,663 cubic meters general cargo

FIGURE 14

MATSON RO-RO

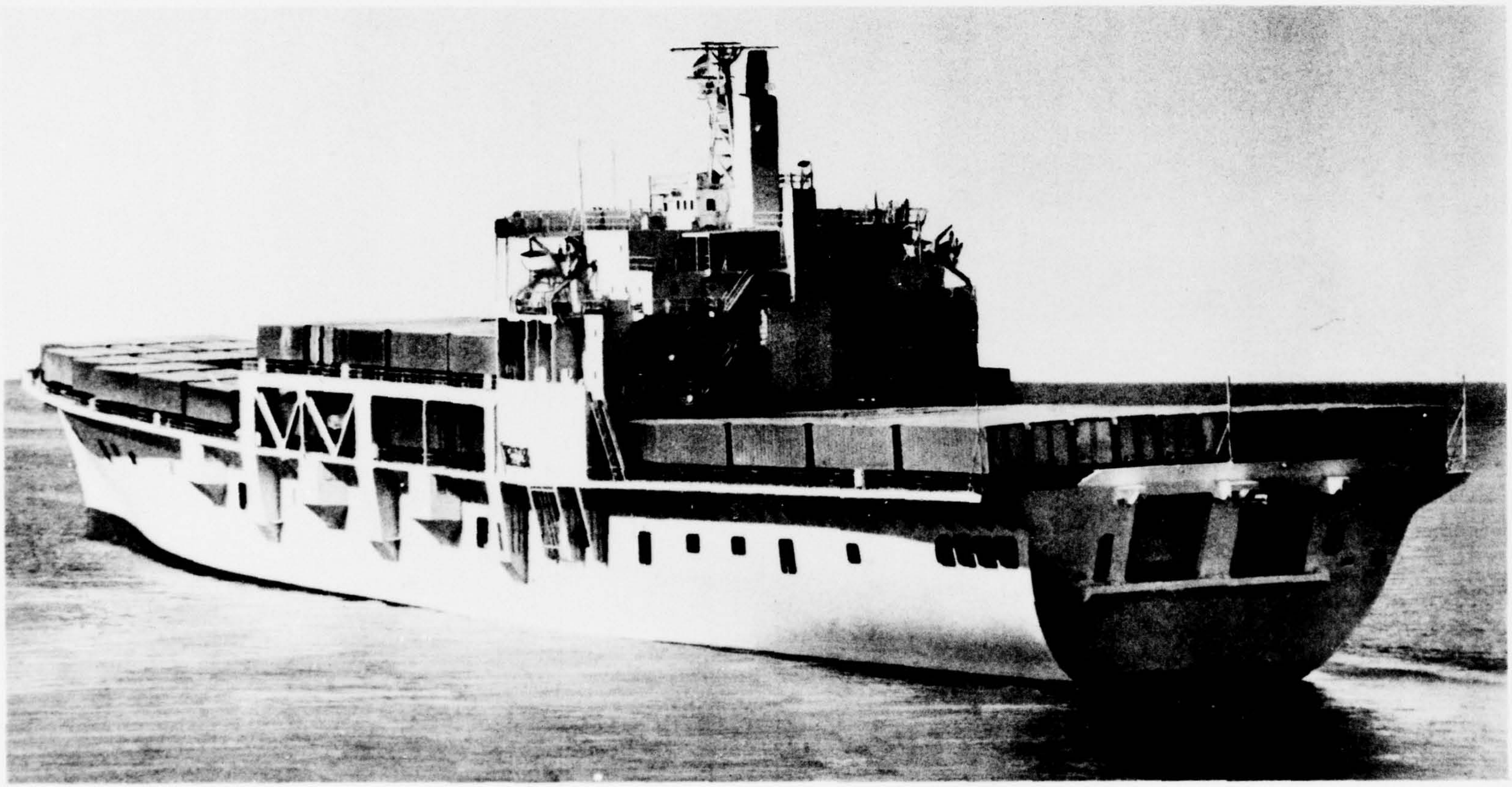


OWNER: Matson Navigation Co.
Puerto Rican Maritime Shipping Authority
YEAR CONSTRUCTED: 1973
LENGTH OVERALL (FT): 700
BEAM (FT): 105
DRAFT (FT): 28

NO. IN SERVICE: 2
4
NO. OF PROPELLERS: 1
DEADWEIGHT TONS: 14,000 $\pm$ 200
SPEED (KTS): 25.0
RADIUS (NM): 6,000
CONTAINER CAPACITY: 260 $\pm$ 20 -40ft. trailers

FIGURE 15

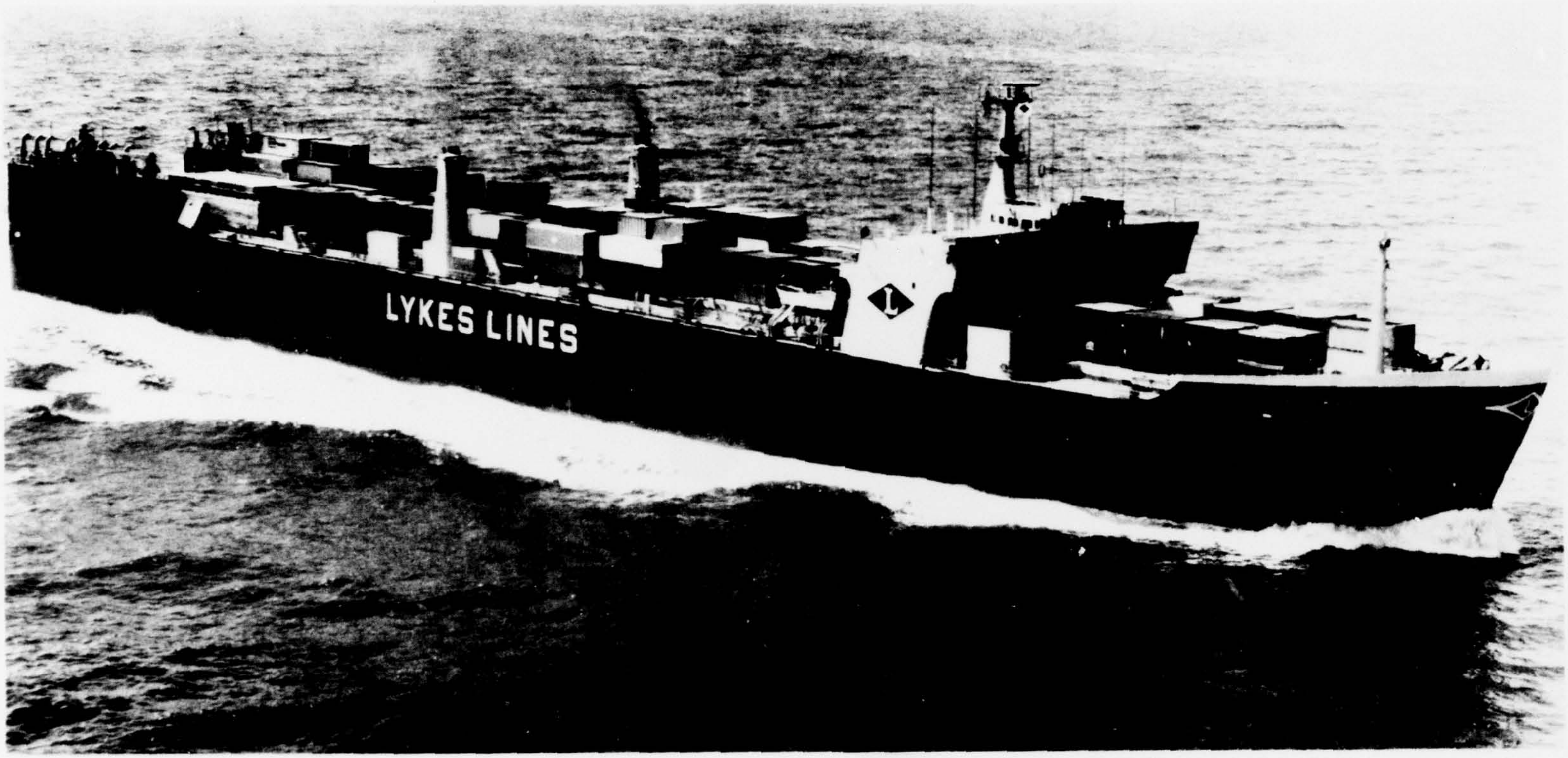
"SUN" RO-RO



OWNER: Pacific Far East Lines	NO. IN SERVICE: 2
Totem Ocean Trailer Express	1
YEAR CONSTRUCTED: 1974-75	NO. OR PROPELLERS: 1
LENGTH OVERALL (FT): 791	DEADWEIGHT TONS: 16,100
BEAM (FT): 105	SPEED (KTS): 24.0
DRAFT (FT): 28	RADIUS (NM): 6,000

FIGURE 16

"SEABEE" BARGE CARRIER



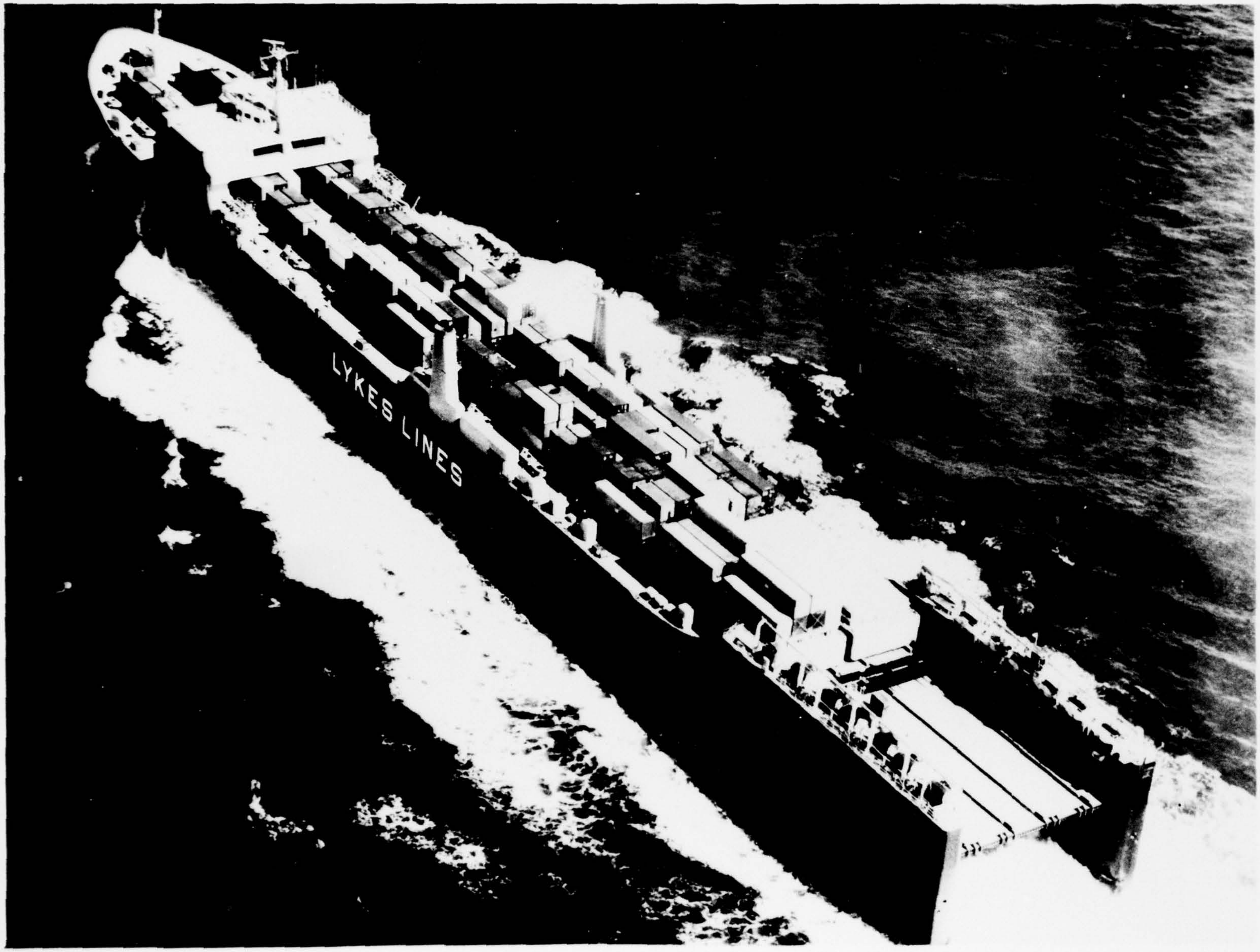
OWNER: Lykes Bros. Steamship Co.
DESIGN: C8-S-82A
YEAR CONSTRUCTED: 1972-73
LENGTH OVERALL (FT): 876
BEAM (FT): 106
DRAFT (FT): 39

NO. IN SERVICE: 3
NO. OR PROPELLERS: 1
DEADWEIGHT TONS: 38,410
SPEED (KTS): 20.0
RADIUS (NM): 16,000
CONTAINER CAPACITY: 1800 TEU <u>or</u> 38 barges* plus 933 TEU

* Each barge 97'-6" x 35' x 16'-11"

FIGURE 17

SEABEE BARGE CARRIER SHOWING ELEVATOR



APPENDIX B

SKETCHES OF TYPICAL INSTALLATIONS

and

PHOTOGRAPHS OF MODEL INSTALLATIONS

Photos by Fairey Engineering, Ltd. Used by permission of Headquarters, U.S. Marine Corps.

FIGURE 18

SL-7 CONTAINERSHIP CONFIGURED FOR VSTOL OPERATIONS

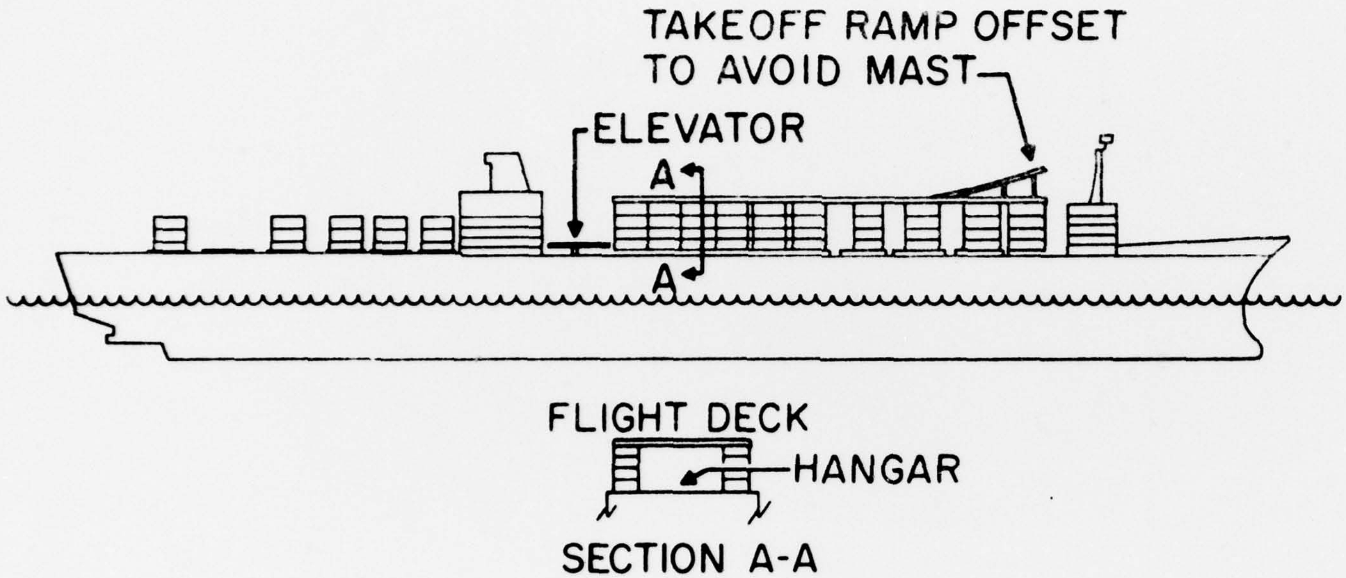


FIGURE 19

"PACESETTER" CLASS CONTAINERSHIP CONFIGURED FOR VSTOL OPERATIONS

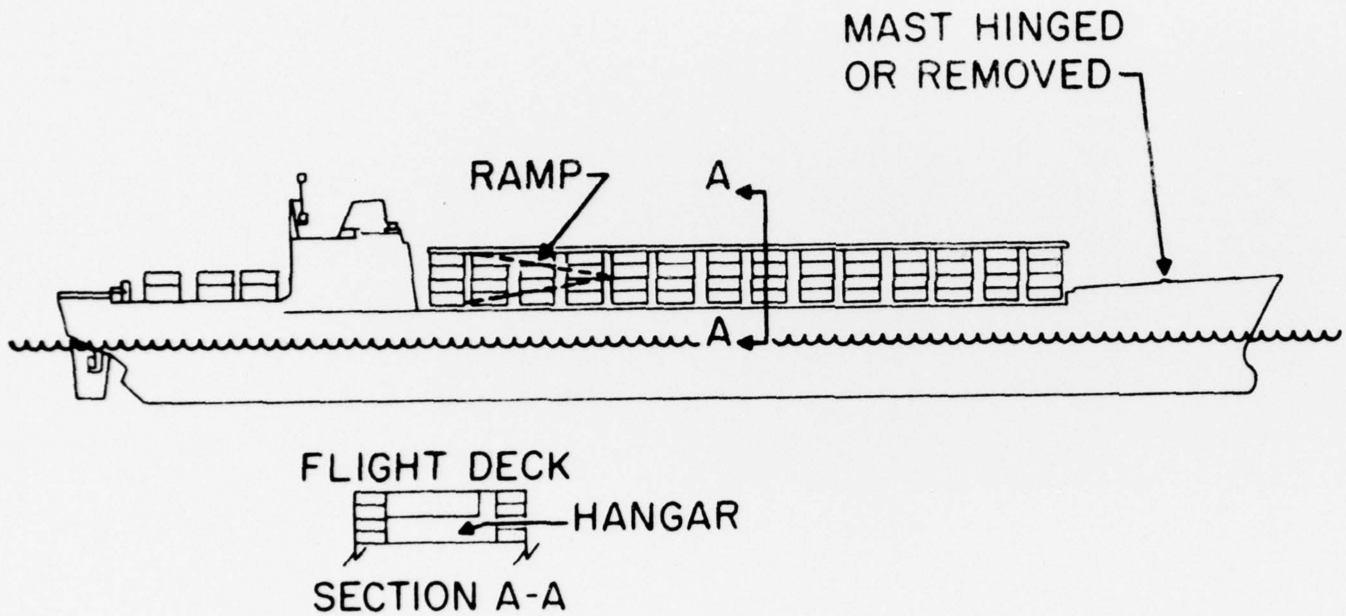


FIGURE 20

AIRCRAFT ON ELEVATOR

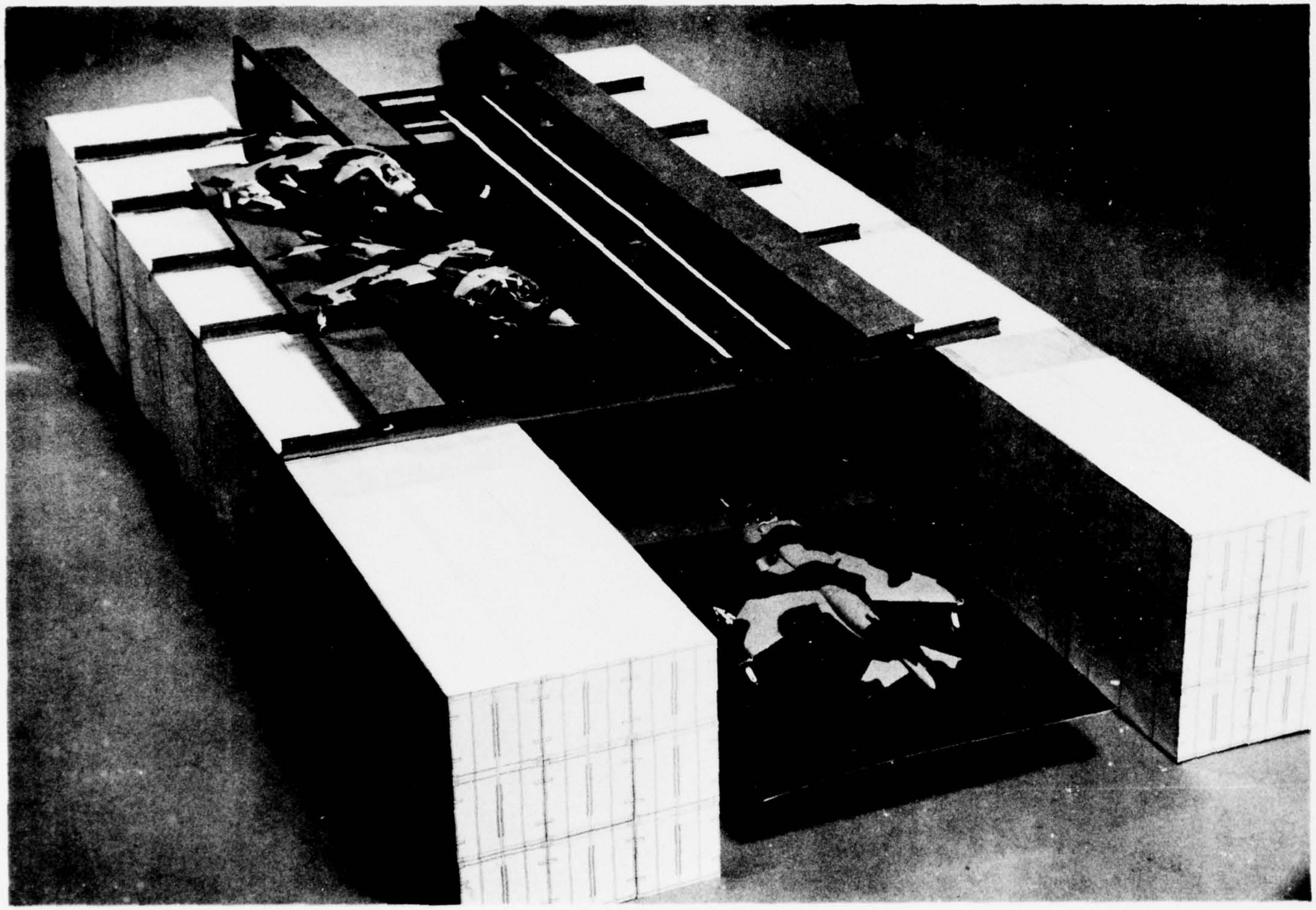


FIGURE 21

FLAT RUNWAY ATOP CONTAINERS

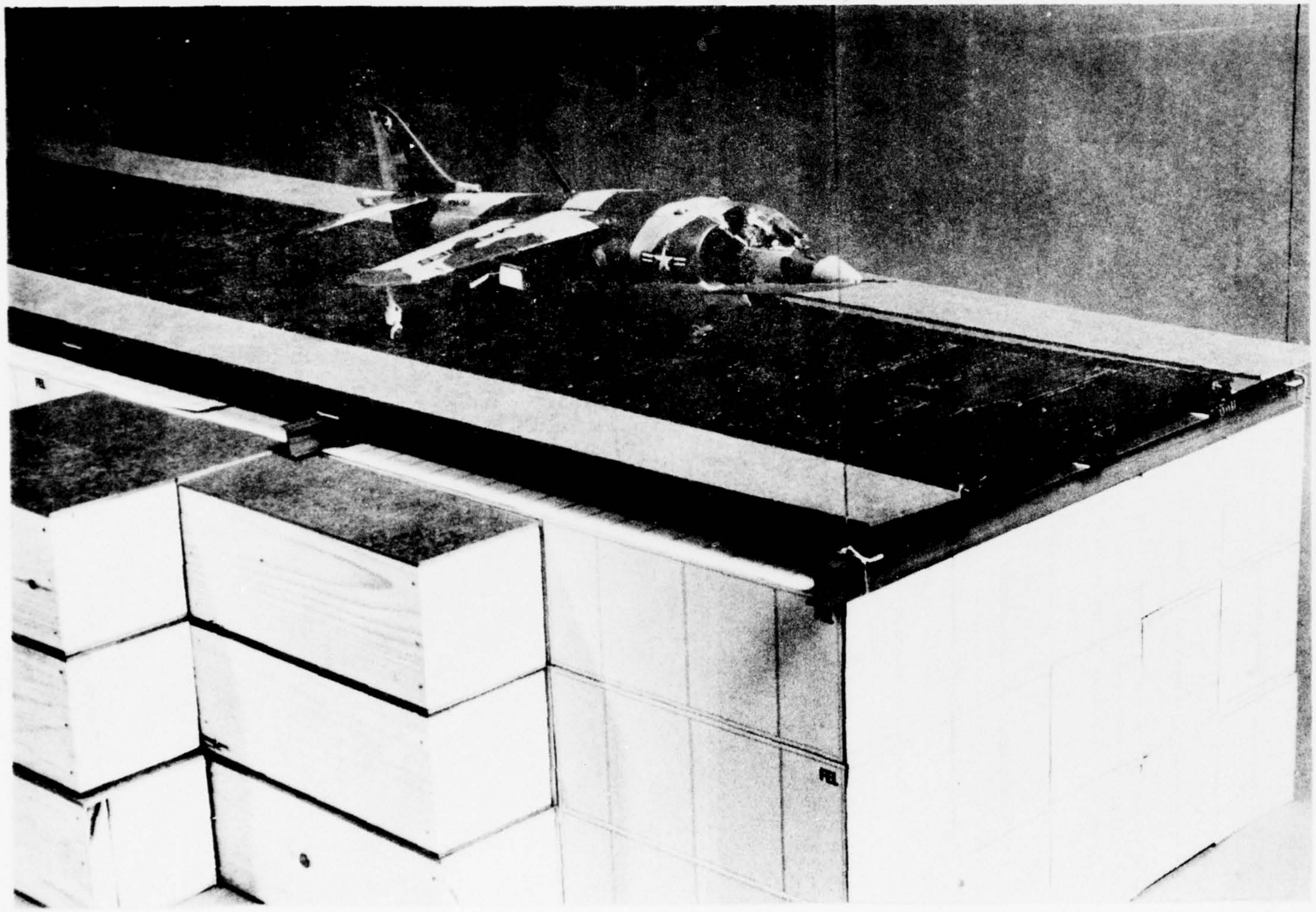
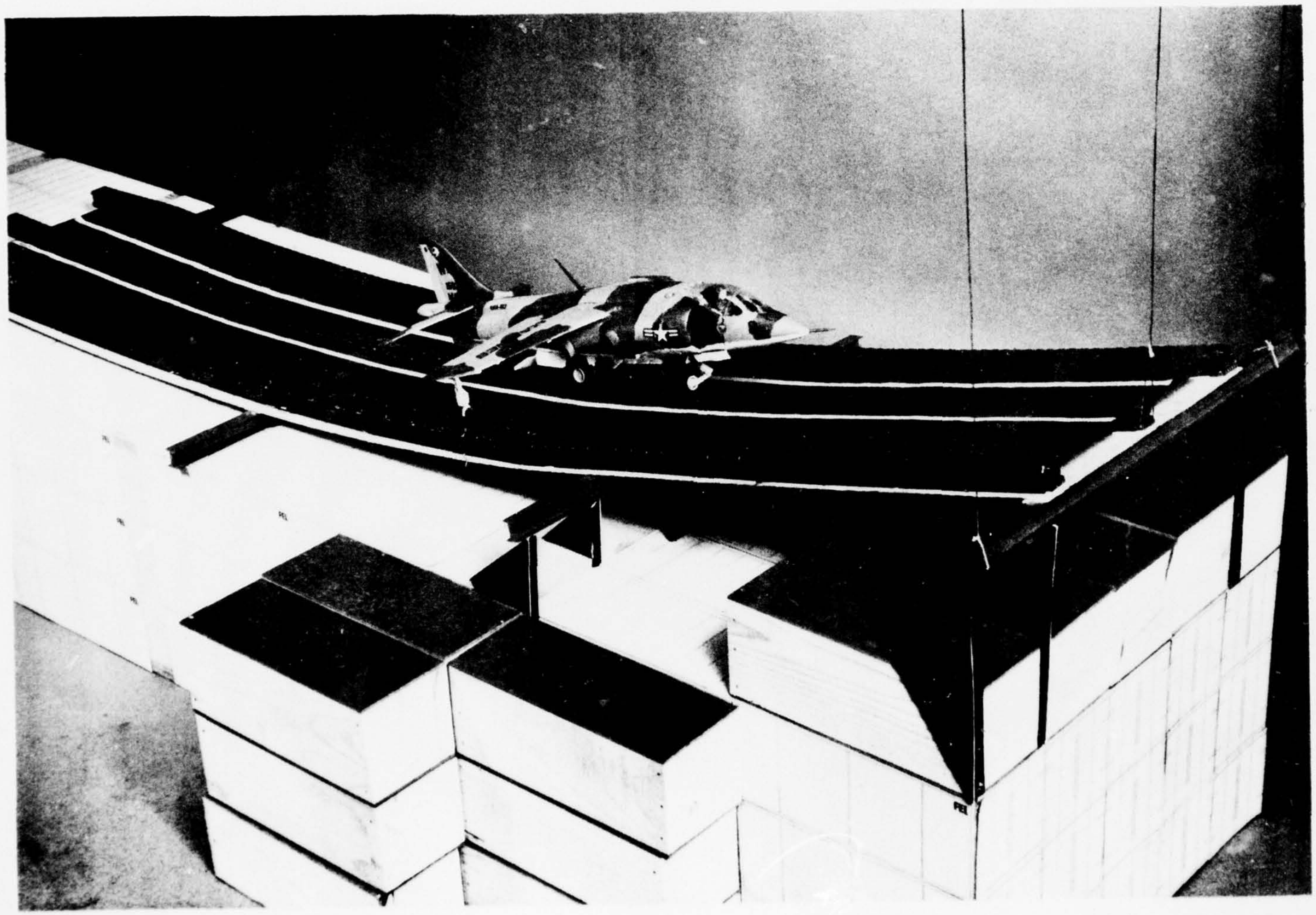


FIGURE 22

"SKI-JUMP" TAKEOFF RAMP



APPENDIX C

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IN

VARIOUS DISCIPLINES

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ARAPHO Program	Naval Air Systems Command	Advanced Systems Directorate (AIR003P1B)	Mr. J.J. Mulquin	C(202) 692-7390/94 A 222-7390/94
Expeditionary Fuel Systems	Naval Civil Engineering Laboratory Port Hueneme, CA 93041	Ocean Systems Division	Mr. N.D. Albertsen Mr. Mark Hollan	C(805) 982-5792 A 360-5792
Containers Aboard Ship and MCESS	Headquarters, USMC Washington, DC 20380	Engr/MT/Gen Sup Branch (Code LME)	COL J.J. Harp	C(202) 697-6959/3618 A 227-6959/3618
Command, Control & Communications	Marine Corps Tactical Support Systems Activity MCB Camp Pendleton, CA 92055	Commanding Officer	COL R.M. Proudfoot	C(714) 725-2618 A 993-2618
On Board Oxygen Generating System (OBOGS)	Naval Air Systems Command Washington, DC 20360	Life Support, Survival & Rescue Br. (AIR-5311B)	Mr. R.H. Ferguson	C(202) 692-9340/7483 A 222-9340/7483
VSTOL Test & Evaluation	Naval Air Test Center Patuxent River, MD 20670	Strike Aircraft Test Directorate (SA-61)	Mr. D.E. House Mr. R. Traskos	C(301) 863-4731 A 356-4731
Sealift Mobility	Chief of Naval Operations Washington, DC	Mobility Plans (OP-405)	CAPT R.K. Leopold	C(202) 695-5274 A 225-5274
Emergency Mobilization of Merchant Ships	U.S. Dept. of Commerce Maritime Administration Washington, DC 20230	Division of Emergency Plans	Mr. Frank B. Case	C(202) 377-3232

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4. TITLE (and Subtitle) Feasibility of Tactical USMC VSTOL Aircraft Operations Aboard Merchant Ships 1990-2000.		5. TYPE OF REPORT & PERIOD COVERED
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Two trends indicate a potential problem in the movement of tactical aircraft, specifically Marine Corps tactical aircraft, to combat areas in a large portion of the world. Reduced numbers of U.S. Navy ships and contained basing and overflight rights may limit access to those combat areas which can be reached by air-refueled ferry flights from U.S. bases. Relatively simple modifications to some newer ships in the U.S. merchant fleet will permit flight operations by present and proposed inventories of USMC vertical and short takeoff and landing (VSTOL) aircraft. Shipborad requirements are identified and

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potential ship installations are suggested. Emphasis is placed on integration of existing or already proposed hardware to increase the tactical air fire power which may be brought to bear in remote geographic areas of national interest.